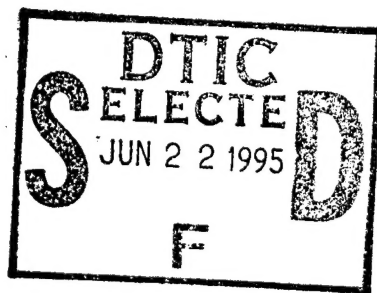


NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA



THESIS

ANALYSIS OF THE ARMY'S DECISION TO CEASE
PROCUREMENT OF M1 TANK ENGINES

by

Weston H. Sanford, III

March 1995

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TANK ENGINES

by

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Captain, United States Army
B.S., Central Connecticut State University, 1984

Submitted in partial fulfillment of the
requirement for the degree of

MASTER OF SCIENCE IN MANAGEMENT

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ABSTRACT

This thesis examines the issues surrounding the potential closure of the sole tank engine production facility in the United States. The analysis will describe the impact of the production facility's closure on both the United States Army's tank fleet readiness and the industrial base. The analysis is based on the FY95 DoD budget which appropriated funds for a service life extension program for existing AGT 1500 gas turbine engines through 1998. This thesis presents three possible alternatives to preserving the tank engine industrial base. The three alternatives are: 1) terminate production, mothball the production facility and develop an alternate source to provide support of existing engines, 2) terminate production, mothball the production facility, while retaining the original contractor for support of existing engines, and 3) terminate production, downsize the current facility, maintain production capability, while retaining the original contractor for support of existing engines. The following factors were utilized to analyze each course of action: 1) workforce issues, 2) costs, 3) mobilization and surge capabilities, 4) spare parts requirements and 5) operational effectiveness considerations. The thesis will provide the chronology of events that led to the Army's determination of a course of action to preserve the tank engine industrial base. This thesis will recommend an alternative to preserving the tank engine industrial base, as well as areas for further study.

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to analyze the impact of the Army's decision to cease production of M1 main battle tank's engine, on its' tank fleet readiness. Additionally, this thesis will present and analyze three possible alternatives to preserving the tank engine industrial base with respect to applicable factors facing the Department of Defense (DoD), Congress and industry.

B. BACKGROUND

The tank engine industrial base is unique and essential to the readiness of the U.S. Army. Although there are other producers of gas turbine engines in domestic and foreign market places, the AGT 1500 has several product-specific attributes, which make it stand out as a unique turbine engine. The end of the Cold War and our decisive defeat of Iraq in the Gulf War brought about a decline in defense spending. Thus, the Army is having to make some difficult decisions in the procurement of its equipment. An unstable world with growing arsenals of high tech weapons is placing ever increasing pressure on U.S. defense planning and procurement. The need for a ready and capable tank force will be paramount in America's ability to influence the actions of other countries which deviate from acceptable behavior. Allowing the tank engine industrial base to go "cold" could jeopardize the future readiness of the tank fleet. Congress has shown its commitment to keeping the tank engine industrial base "warm" by providing funding that will allow it to remain operational for the near term.

Currently, the only open factory in the United States capable of producing the AGT 1500 gas turbine engine is located in Stratford, Connecticut. The Stratford Army Engine Plant (SAEP) is the only facility to ever produce the AGT 1500 gas turbine engine. The last AGT 1500 gas turbine engine is scheduled to come off the production line in the spring of 1995. After this date, there are no foreign or domestic requirements

for the engine. The M1 tank upgrade program that is currently underway, does not require the installation of newly-manufactured tank engines. Should the Army decide both to let the tank engine industrial base go "cold" and to postpone the Block III tank, it is possible that the ability to produce a newly-manufactured tank engine will cease until sometime after the year 2000.

As a result, the producer of the engine, AlliedSignal, is attempting to "right-size" its operation and gain a portion of the engine overhaul work. Consequently, the decision both to let the manufacturing of new tank engines cease and to embark on a plan to utilize depot and contractor overhauled engines in the M1A2 Upgrade Program, has sparked an interesting and at times, emotional debate between the AlliedSignal, DoD and Congress. Throughout this debate, the Army has developed numerous courses of actions to help it make the best decision regarding the preservation of the tank engine industrial base.

The following are three options for maintaining tank engine production capabilities that the Army evaluated: 1) Mothball or sell the current facility, move operations to another facility and find another prime contractor, 2) Mothball or sell the current facility, move operations to another facility while retaining AlliedSignal as the contractor 3) Retain AlliedSignal as prime contractor, downsize both the current facility and workforce to meet current Army requirements. Even these proposed alternatives may not be able to keep the tank engine industrial base in existence long enough to transition into the Block III Main Battle Tank and its new propulsion system. The U.S. Congress instructed DoD to direct funding to AlliedSignal to perform engine overhaul work. This additional work is intended to keep the contractor operational for the near term. DoD has not fully embraced this redirection of funds, as they contend it more expensive than utilizing existing Government depot assets to perform this work.

Hence, the decisions DoD is making, concerning both how to keep a critical technological capability available and how to hold equipment readiness at the highest possible levels while meeting budgetary constraints, typifies some of the problems it must grapple with as the drawdown of military forces continues. These decisions are not

easy ones. There are political and National Security considerations which play key roles in decisions that affect our defense industrial base preservation.

C. THESIS OBJECTIVES

The objectives of this thesis are to provide the Army, DoD, and Congress an insight into what should be done with the only tank engine factory in the United States. By utilizing a case study format, a process to analyze this issue is presented that can be applied to other programs that are experiencing related concerns and issues.

D. RESEARCH QUESTIONS

1. Primary

Upon completion of new M1 tank engine production in 1995, should DoD either keep open, on a limited production basis, the only tank engine production facility in the United States, or close it?

2. Subsidiary

- How will the absence of tank engine production affect readiness of the armored forces?
- Will skilled workers be lost?
- How long will it take to retrain the force?
- What will it cost the Government both to close the facility and to reopen it?
- What will the impact of plant closure have on the subcontractor base?
- How will the spare parts requirements for existing tank engines be satisfied?
- Under what conditions should DoD attempt to maintain a minimum tank engine production capability for contingencies as mobilization, or foreign military sales (FMS)?
- How long will it take to reestablish a closed engine production line and produce sufficient engines to meet demand?

E. RESEARCH SCOPE AND LIMITATIONS

This case study focuses only on U.S. tank engine production and the effects of DoD acquisition strategies and plans on a single source within the defense industrial base. As production of the engine is scheduled to cease in 1995, but the anticipated service life of the M1 series tank will extend beyond the year 2010, the scope of this thesis will be limited to the impact on mobilization of the industrial base and tank fleet readiness through the year 2010. It might also be noted that a Block III tank may be ready for production near the year 2000, and that it will most likely employ an engine different than the current AGT 1500. As this issue is currently being analyzed and updated by the Army, some of the data utilized at the time this thesis was written, may have been superceded by more current information.

F. METHODOLOGY

The thesis research and analysis will examine the industrial base issues and defense acquisition policies that affect decisions concerning preservation of the tank engine industrial base. The thesis will then develop courses of action on methods proposed by DoD, the contractor and Congress to sustain the tank engine industrial base. This thesis will analyze the effects of the courses of action with respect to the following issues: 1) effects on the tank engine industrial base workforce, 2) costs required to implement each option, 3) effects on the subcontractor base, 4) impact on the mobilization requirements, and 5) impacts on operational readiness.

G. LITERATURE REVIEW

Background and policy information was obtained from the Defense Technical Information Center (DTIC) and Defense Logistic Studies Information Exchange (DLSIE) databases, professional journals, and published studies. Information was also obtained by conducting a personal visit, as well as corresponding with, Program Manager (PM)-

Abrams Tank System and U.S. Army Tank-Automotive Command, Warren, Michigan.
AlliedSignal, located in Stratford, Connecticut was an additional source for technical data.

II. BACKGROUND

A. THE DEFENSE INDUSTRIAL BASE

The economic and political issues surrounding the preservation of the tank engine industrial base, are problems DoD has faced after each major war of this century. Throughout U.S. history, we have mobilized our industrial base to provide the machinery of war to defeat our enemies. The decision makers in this country follow the ending of hostilities with the dismantling of the defense industrial base. During these postwar times, DoD and industry have attempted to develop the optimum level of industrial base. Without an effective industrial base, the systems necessary for our Armed Services to deter aggression and defeat our enemies will not be in place. In 1988, the Center for Strategic and International Studies (CSIS), published a study defining the industrial base as the

...aggregate ability to provide the manufacturing, production, technology, research and development and resources required to produce materials for the common defense of the U.S. [Ref. 1, p. 12].

The CSIS study assumes any firm that provides goods for national defense, whether commercially-owned and operated, Government-owned and operated, domestically or foreign-based, is part of the industrial base. This study also introduces the belief that the defense industrial base contributes to deterrence of war in three ways. They are: peacetime efficiency, technological competitiveness, and flexibility in a crisis.

The industrial base consists of the following three elements:

- **Full-Service Prime Contractors:** Contractors that provide manufacturing capacity, as well as system technical support, design and engineering capabilities and logistical support. These prime contractors may operate Government-owned and contractor-operated (GOCO) or contractor-owned and contractor-operated (COCO) facilities. There are three active full-service prime contractors servicing the tracked vehicle industrial base [Ref. 2, p. 2].

- **Vendor Base:** Contractors or subcontractors that manufacture subsystems or end-item assemblies to support the tracked vehicle industrial base. Included in the vendor base are two arsenals: Watervliet, which manufactures cannons; and Rock Island, which manufactures gun mounts and recoil mechanisms.
- **Depots:** Supply support through the disassembly, overhaul and repair of tracked vehicles and components. There are currently three active depots supporting the tracked vehicle industrial base: Anniston Army Depot (Heavy Armor), Red River Army Depot (Light and Medium), and Letterkenny Army Depot (Howitzers).

At the outset of the Cold War, the U.S. defense planners realized that matching the Soviets one-for-one in equipment and manpower would not be a cost-effective means of deterrence. The DoD and Congress believed that developing superior technology was the best tactic to win the Cold War. The industrial base's ability to develop superior weapon systems allowed the Armed Forces to field weapon systems of higher technology than the Soviets. With the end of the Cold War and communism's failure in the Soviet Union, many persons felt that continuing this course of action was not appropriate. Today, some people believe that with a lack of a superpower country to threaten us militarily, preservation of the tank engine industrial base is not warranted. A review of recent events in Panama, Haiti, Bosnia, Somalia, Rwanda, North Korea, and Iraq, illustrates that deterrence may not always preserve the peace. Apparently, the U.S. industrial base needs to remain capable of providing rapid reconstitution of the equipment necessary for the U.S. military to deploy and successfully defeat any enemy force.

B. THE TANK ENGINE INDUSTRIAL BASE

AlliedSignal produces the AGT 1500 gas turbine engine for the M1 tank at the Stratford Army Engine Plant (SAEP), Stratford, Connecticut, a GO-CO facility. The SAEP also produces engines for Army helicopters, Navy Landing Craft Air Cushioned (LCAC) vehicles, and commercial applications. AlliedSignal utilizes both Government

and contractor-owned equipment to produce these engines. The Government has a total investment of approximately \$278.9M (37,187 inventory items) in SAEP, including \$49M worth of industrial plant equipment (IPE) [Ref. 3, p. 1]. Key Government-owned equipment includes: flexible manufacturing systems, computer numerically controlled (CNC) Machining, and unmanned material handling systems. There are 214 pieces of AlliedSignal-owned machinery and equipment used for AGT 1500 manufacturing [Ref. 3, p. 1]. Examples of unique machinery utilized in the production of the AGT 1500 are: CBN (Cubic Borazon Nitride) gear tooth grinders, laser welders, horizontal and vertical CNC machinery centers, and a laser machining center. AlliedSignal paid \$1.654M in 1992, for the use of Government IPE in its commercial production of engines. SAEP has the capacity to produce 3,000 turbine engines per year. The plant also has the capability for full engine testing of turboshaft, turboprop, turbofan, and industrial turbine engines.

AlliedSignal's annual sales are estimated at \$682M, of which \$451M was derived from SAEP engine sales (1993). AlliedSignal generates the balance from its other facilities, through the sale of spare parts, and remanufactured, overhauled, and other engine production. In AlliedSignal's strategic plan, it forecasts sales shrinking yearly from \$451M in 1993 to \$340M in 1997. This plan assumed continued new AGT 1500 production for Phase I of the M1A2 Upgrade Program, remanufactured engines for Phase II, the FMS to Saudi Arabia, and spares. Reductions in military procurements and the Army's decision not to purchase remanufactured engines, forced AlliedSignal to reevaluate their ability to remain in the business of producing AGT 1500 engines and spare parts. The 1993 Future Years Defense Plan (FYDP) did not have any requirements for new U.S. military engines beyond FY93. The M1A2 Upgrade Program includes engines overhauled at Anniston Army Depot.

If the 1993 FYDPs were implemented, excluding AlliedSignal from the M1A2 Upgrade Program, the production line would go "cold" in May 1995 [Ref. 4, p. 2]. AlliedSignal then would consider moving the production of commercial engines to a less costly facility. Military engine production remaining at SAEP would generate \$35-50M a

year [Ref. 3, p. 2]. This amount would not be sufficient for AlliedSignal to continue support of the AGT 1500.

An extended production line shutdown results in: certain skills, equipment, and facilities not being ready or available for contingency production or FMS requests. After a one-year shutdown, the restart costs are estimated at \$42M (1991 Abrams Closure Study with Smart Shutdown). TACOM estimates that it will take AlliedSignal three years to ship the first engine to the Army after regeneration of the production line begins. An important factor to consider is the lack of any other qualified producer of the AGT 1500 engine. There are several manufactures of gas turbine engines available, who, given the required level of funding and sufficient time, could produce the AGT 1500.

The departure of AlliedSignal's engine production capabilities from the tank industrial base, leaves only Anniston Army Depot capable of supporting the Army's tank engine overhaul and repair needs for the next 20-25 years. Table 1 depicts the services provided by AlliedSignal and ANAD.

LIFE CYCLE FUNCTION	CAPABILITIES	
	Anniston Army Depot	Stratford Army Engine Plant
R&D		X
Sub-system Integration		X
Manufacturing		X
Remanufacturing		X
Technology Infusion		X
Overhaul & Repair	X	X
Vendor Management		X
Wartime Deployment	X	X
Field Support	X	X

Table 1. Tank Engine Industrial Base Capabilities

If production of the AGT 1500 ends in May 1995, the Army would have the option of divesting of its investment in SAEP. The Army could offer to sell the key IPE to AlliedSignal rather than renting it. AlliedSignal may not elect to acquire some of the Government equipment due to its uniqueness or age.

C. THE AGT 1500 GAS TURBINE ENGINE PROGRAM 1976-1992

Prototype development of an experimental new main battle tank for the Army, the XM1, began in the 1970's. The Army conducted design competition between Detroit Diesel Allison Division of General Motors Corporation (powered by Teledyne continental Motor's AVCR 1360-2 diesel engine) and Chrysler Corporation Defense Division (featuring AVCO Lycoming Division's AGT 1500 Turbine Engine). The Army subjected both engines to considerable testing and evaluation. The testers placed primary emphasis on performance, maintenance, weight, and size factors [Ref. 5, p. 1].

Teledyne Continental Motor's prototype tank engine differed from diesel engines utilized in previous main battle tanks. This diesel employed variable compression ratio (VCR) pistons and unisteeel cylinders. These components, in addition to high boost pressure operation, reduced the size and weight of the diesel, while providing higher power output than comparable diesel engines.

The Army developed the AGT 1500 turbine engine to apply to armored ground systems, the advantages of low engine weight, long life, and low maintenance. These desirable attributes were demonstrated by aircraft turbine engines currently in service. AVCO Lycoming Division employed high inlet temperature, blade cooling, and regeneration to improve fuel economy of the turbine engine.

From 1973 to 1976, the Army conducted validation tests and studies to determine which technology to incorporate into the XM1 tank. Although riskier and not as mature as diesel engine technology, the turbine ultimately defeated the diesel. At the time, the Army believed that the turbine would provide better long-term potential for growth in performance and durability [Ref. 5, p. 1]. On November 12, 1976, the Department of Defense selected Chrysler's tank proposal, utilizing the turbine engine. The Department of the Army and DoD Engine Review Committees delayed production of the engine until September 1979. Both agencies considered the turbine's test mileage less than desirable and recommended additional testing of the engine. AlliedSignal delivered 110 engines from September 1979 through August 1980. AlliedSignal's second year production

schedule was 30 engines per month [Ref. 2, p. 21]. As of November 1993, AlliedSignal had produced approximately 11,081 engines for the U.S. Army.

The U.S. Army Tank-Automotive Command (TACOM) procures spare and repair parts for the DoD wholesale inventory based on needs forecasted by the Requirements Determination and Execution System. In 1992, TACOM realized that there was no future requirement for the manufacturing of new AGT 1500's. There was a concern that due to elimination of the need for production, materials due-in under existing contracts would exceed forecasted requirements. When these conditions occur, the system generally recommends termination of orders that exceed the maximum quantity authorized to be on hand and due-in. Table 2 illustrates the amount of engines and modules that were considered in May 1992 to be in excess of requirements.

TACOM also procures spare and repair parts for Foreign Military Sales (FMS) customers. TACOM included within its yearly engine production requirements, those AGT 1500's designated for FMS, as well as those engines destined for other DoD requirements. Thus, it was very important for the planners at TACOM to consider the impact on FMS engine production of a decision to curtail procurements for DoD requirements.

In May of 1992, on-hand and due-in AGT 1500 engines and four related modules, exceeded their system-computed requirements objectives [Ref. 6, p. 3]. TACOM employed as part of their termination decision process, the Economic Contract Cutback Model. The model illustrated to TACOM that termination of the engines and the rear gear box modules would not be economical. TACOM management decided to utilize a partial termination of the contract that applied to excessive quantities of the other three engine modules. TACOM did not terminate any AGT 1500 engines due-in to DoD inventory. They based their decision on both indications the model produced, and the belief that termination of production would have a negative effect on the cost of engines designated for FMS. Table 3 depicts the costs to terminate the contract and potential savings of this action [Ref. 6, p. 3].

Item	Quantity				Potential Excess Value Millions \$
	Replacement Price *	Requirements Objective	Assets Available	Potential Excess	
AGT 1500 Engine	\$ 386,270	378	799	421	\$162.60
Forward Module	\$104,610	238	721**	483**	50.5
Rear Module	\$200,797	238	617**	379**	76.1
Rear Gearbox	\$92,154	168	419	251	8.1
Accessory Gearbox	\$21,372	150	423**	273**	5.8
Total					\$303

Table 2. Excess Engines and Modules, 1992 [Ref. 6, p. 4].

* Replacement price is the average cost based on previous purchase and is used as the value of the AGT 1500 engine

** Includes the due-in quantities being considered for termination. Total value of assets exceeding the Requirements Objective after planned termination of \$34.4M of modules would be \$368.7M.

Item	Excessive Due-In Quantity	Contract Costs	Termination Costs	Potential Savings
Forward Module	123	\$ 23.10	\$ 17.20	\$ 5.90
Rear Module	63	\$ 9.80	\$ 7.30	\$ 2.50
Accessory Gearbox Module	74	\$ 1.50	\$ 1.10	\$ 0.40
		\$34.40	\$25.60	\$8.80
M\$				

Table 3. Potential Savings From Contract Termination [Ref. 6, p. 3].

1. DoD Inspector General

The DoD Inspector General (IG) reviewed TACOM's strategy for addressing the excess modules problems and recommended changes to the selected course of action. The IG advised TACOM to use excess engines and to assemble excess modules into complete engines. These engines could fill some of the FMS requirements for new AGT 1500's. By utilizing this approach, TACOM would use approximately 310 engines currently in inventory to partially satisfy the 814 engine FMS requirement for 1993 and 1994. The approximate value of the 310 engines was \$130M.

TACOM considered this option, but asserted that it must sell the engines to FMS customers at standard price as required by law, which includes a mark-up for TACOM's handling costs. This mark-up increases the cost of the engine to one substantially higher than the current contract purchase price per engine (\$512,984 versus \$413,953) [Ref. 6, p. 4]. TACOM was unaware of a DoD policy that grants the Army Chief of Staff the authority to deviate from standard price to provide assets to FMS customers.

Using this information, the DoD Inspector General recommended that TACOM reverse its decision to partially terminate the procurement of excessive quantities of AGT 1500 modules. The IG stipulated that TACOM must first determine if it was economical to use the modules to satisfy FMS engine requirements.

The IG did take into account that TACOM might incur some additional costs by using excessive quantities of DoD assets to meet the FMS need. The additional costs would arise from modifications to the engine and the assembly of the respective modules into a complete engine. The reduction in the number of engines produced for FMS would also lead to contract termination costs. The IG estimated that TACOM could avoid the estimated \$25.6M termination costs related to excess modules due-in, by selling the 310 engines valued at \$130M to FMS customers [Ref. 6, p. 5].

2. Partial Contract Termination

The Department of the Army (DA) thoroughly evaluated the DoD IG recommendation to reverse the decision to partially terminate the AGT 1500 Modules. TACOM analyzed the recommendation with regard to the following terms: industrial base retention, spare asset availability, cost, ability to sell spares to FMS customers, and future AGT 1500 engine and module requirements. TACOM deemed the continued purchase of excessive quantities of AGT 1500 engine modules not practical for the following reasons:

- TACOM had no assured requirement for the terminated modules because of the uncertainty and risk associated with sales to foreign customers.
- There were no requirements for additional spares because stock on-hand was already beyond the Requirements Objective (RO), and reductions in Army force structure could further decrease demands.
- TACOM expected a net recoupment of \$17.4M, based on a total contract value of \$34.4M and an estimated termination liability of \$17.0M.

If TACOM reinstated the modules, the net recoupment would be less due to the added cost of the additional line-items needed to convert modules to complete engines [Ref. 4, p. 2]. The net effect of the terminating modules was to reschedule other deliveries. The revised schedule mitigated the cost impact of the termination by delaying the impact to the last years of contract deliveries (1993-1994), where less cost had been incurred. This produced the same results anticipated by the IG.

TACOM also concluded that stock levels in excess of the RO would actually increase as the Army force structure declined. Therefore, it initiated termination action to cancel modules remaining on contract, but not delivered as of July 1992. The only exception was eleven reduction gear boxes. A comparison of termination costs versus reinstatement costs, demonstrated that a continuation of the termination was less costly. TACOM, faced with the lack of assured requirements for terminated contract modules, stock on-hand identified as above the RO, and the recoupment of \$17.4M, supported termination of the modules as the prudent business decision to make.

3. Sale of Spare Engines and Modules

TACOM agreed to reevaluate the IG's recommendation to sell excess quantities of AGT 1500 engines and modules to satisfy FMS requirements. TACOM felt that this option was not possible to implement because of the requirement to maintain the tank engine industrial base until the year 2001. Other considerations which weighed heavily in their analysis were: prospect of future U.S. and FMS orders, providing warranty coverage, AlliedSignal's resistance to support engineering change proposal (ECP) applications, and retesting of engines.

In making their evaluation, TACOM studied the initial asset and contract delivery schedule as shown in Figures 1 and 2 (p. 21). Figure 1 displays the asset position and the pre-termination delivery schedules for 1992 through 1995. Assets on-hand include the substantial requirements projected to support operations Desert Shield and Storm. As mentioned earlier, the short duration of the war and the Soviet Union's decreased threat projection, seriously curtailed the demands for engines and modules. Figure 2 illustrates the asset status after termination of the modules, the post termination delivery schedules, and the annual reduction in engines.

Army Regulation 710-1 defines excess stock as assets beyond the maximum retention level. Using this definition, TACOM did not consider the engines and modules cited by the IG as excess. TACOM assumed the "excess" cited by the DoD IG was assets beyond the RO. Table 4 depicts the asset picture as of February 4, 1993. Table 5 illustrates the due-in status, to include Direct Cite, Defense Business Operating Fund (DBOF) assets, and terminated modules. The DBOF spare (FMS) engines and modules were assets scheduled for direct shipment to foreign customers. Implementing regulation AR 37-100-91 directs DBOF to fund assets per the customer pass-through requirement. FMS customers reimburse DBOF for its expenses from a direct cite reimbursable account upon delivery of assets. TACOM scheduled the sale of the engines to be at the FMS price, with all add-ons, not at the standard Army Master Data File (AMDF) price. FMS

	RO	Maximum Retention	Total Assets
Engine	434	975	851
FWD	296	1519	483
Rear	279	1764	439
RGB	186	814	418
AGB	163	872	301

Table 4. Asset Status 4 Feb. 93 [Ref. 4, p. 4].

Contractual	Due-In Picture				
	Engine	Forward	Rear	RGB	AGB
FMS (Direct Cite)					
Production/Spares					
CY 93/94	738	0	0	0	0
DBOF					
Spares (Army)	0	0	0	11	0
DBOF Spares (FMS)					
(Direct Ship)	74	59	63	54	0
Terminated*					
Spares (Army)	0	123	62	0	74
*DoD IG Recommended Reinstatement					

Table 5. AGT 1500 Delivery Quantity Reduction, As of 1 Feb. 93 [Ref. 4, p. 9].

customers were unwilling to incur any termination costs caused by TACOM's cancellation of requirements. TACOM's cancellation of contracted deliveries would result in DBOF bearing the full termination cost of the contract. This led TACOM to believe that using assets from stock would drive FMS customers to reduce their engine requirements. This in turn would reduce DBOF projected income. As DBOF's schedule for foreign shipments was for the near term, TACOM felt it wise not to terminate the assets on contract that were designated for FMS customers. TACOM's analysis did not consider designated FMS direct shipment spares as possible termination candidates. TACOM determined that it was not economically feasible to sell spare engines from stock to FMS for the following reasons: technical factors, industrial base retention and cost. The following is a description of each factor:

a. *Technical Factors*

(1) TACOM does not update engines in stock to the most current ECP configuration. Additionally, AlliedSignal does not provide a failure-free and systemic defect warranty for these engines. FMS customers were not willing to accept engines from stock because of these factors. The contractor was not willing to support: configuration upgrade, retesting of engines, and warranty coverage on engines and modules in Army stock. TACOM would support configuration upgrade and retesting, but did not want to become involved with warranty issues on the engine and modules. The complexity of warranty issues, and their unfamiliarity with providing warranties were TACOM's justification for this position.

(2) TACOM has no established organizational structure to develop and administer a warranty as required by the FMS customer. With the downsizing of its workforce, TACOM did not want to incur additional workload for its employees.

(3) There is little data concerning the AGT 1500 engine's ability to be repeatedly rebuilt and overhauled. TACOM expressed a concern that with this lack of data, there could be a problem with long-term reliability and cost-effectiveness of engines and modules overhauled multiple times. Therefore, with the AGT 1500's ability to be repeatedly overhauled in question, TACOM was reluctant to utilize quantities of engines from stock. The retention of the new engine production capacity minimizes the risk of needing new engines in the out years when the industrial base had ceased to exist.

b. *Industrial Base Retention*

(1) The AGT 1500 manufacturing base is essential to tank manufacturing capability. The Program Executive Office, Armored Systems Modernization, (PEO, ASM) required the engine manufacturing base remain viable until completion of the M1 Series upgrade program in the year 2001.

(2) At the time of the analysis, there were potential U.S. and FMS requirements. Under this schedule, AlliedSignal planned final engine delivery for December 1994. Based on an 18 month Production Lead-time (PLT), the reorder point necessary to avoid a break in production was June - July 1993, [Ref. 4 p. 5].

(3) The sale of new engines from stock could have caused a break in production, for each one sold from stock would have correspondingly reduced the number required from the production contract.

(4) A break in production generates a nonrecurring restart cost of \$42M, in addition to the engine unit price, and requires 24 - 36 months for the Army to receive the first engine.

(5) Prepositioned war reserve requirements were unknown and there was uncertainty concerning stock funding of depot-level repairables and its impact on wholesale demands.

c. Cost

(1) The following is a list of cost factors used to evaluate possible courses of action:

- Termination: The actual cost of the terminated quantities.
- Equitable Adjustment: The cost adjustment applied to the remaining contract quantities due to the termination.
- Severance Benefits: Costs associated with layoff of the workforce.
- Idle Plant: Costs associated with maintaining the idle facility.
- Line Reduction and Closeout: Costs associated with ending AGT 1500 production.
- Spares Conversion: Costs of converting spare engines to production configuration.

(2) TACOM developed four proposed selling prices: Contract, AMDF, Material Management Proposed, and Minimums.

- AR 37-60 provides the guidelines to establish the AMDF selling price.
- The Material Management Proposed selling price was based on average contract prices, ECP applications, and warranty.
- The minimum selling price was based on an exception to AR 37-60, which authorizes sale at 50 percent of AMDF if:
 - Asset totals are beyond the Authorized Force Acquisition Objective (AFAO).
 - Sold only to FMS Customer.
- Table 6 illustrates the cost impact and net recoupment associated with each selling price.
- Except for the contract selling price, all other selling prices do not include a systemic defect warranty. It was the Army's position that becoming involved in providing warranties to FMS customers would incur an unacceptable level of financial and political risk.

DOD IG Recommendation				
Recoupment				
	Contract	AMDF	Proposed	Minimum
Total Cost	\$71.2M	\$71.2M	\$71.2M	\$71.2M
Recoupment	\$202.8M	\$191.0M	\$163.3M	\$112.7M
Net				
Recoupment	\$131.6M	\$119.8M	\$92.1M	\$41.5M

Table 6. AGT 1500 Delivery Quantity Reduction [Ref. 4, p. 12].

The issue of satisfying FMS tank requirements by utilizing AGT 1500 engines and modules from stock was extremely complex. The Army estimated that there were potential cost savings ranging from \$41.5M to \$131.6M. The Army believed that other factors outweighed the cost benefit. The Army also considered the following: the retention of AGT 1500 industrial base, uncertainty of future war reserve requirements, impact of stock funding depot level repairables, financial and political risk in providing warranties, costs associated with breaks in production, and the reliability of rebuilt engines and modules. With these considerations in mind, the Army elected to retain new spare

engines and modules in inventory. This would minimize the near-term risk of meeting demand for new engines and modules.

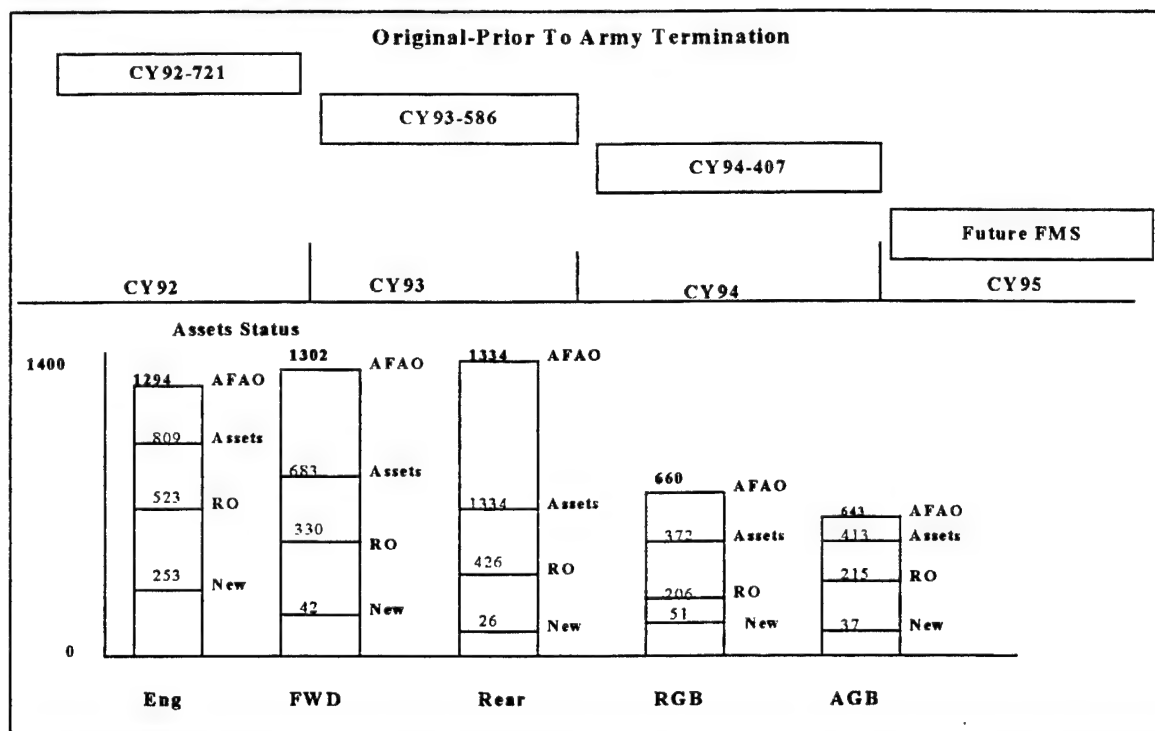


Figure 1. AGT 1500 Engine and Module Delivery Schedule As of March 1992 [Ref. 4, p. 10].

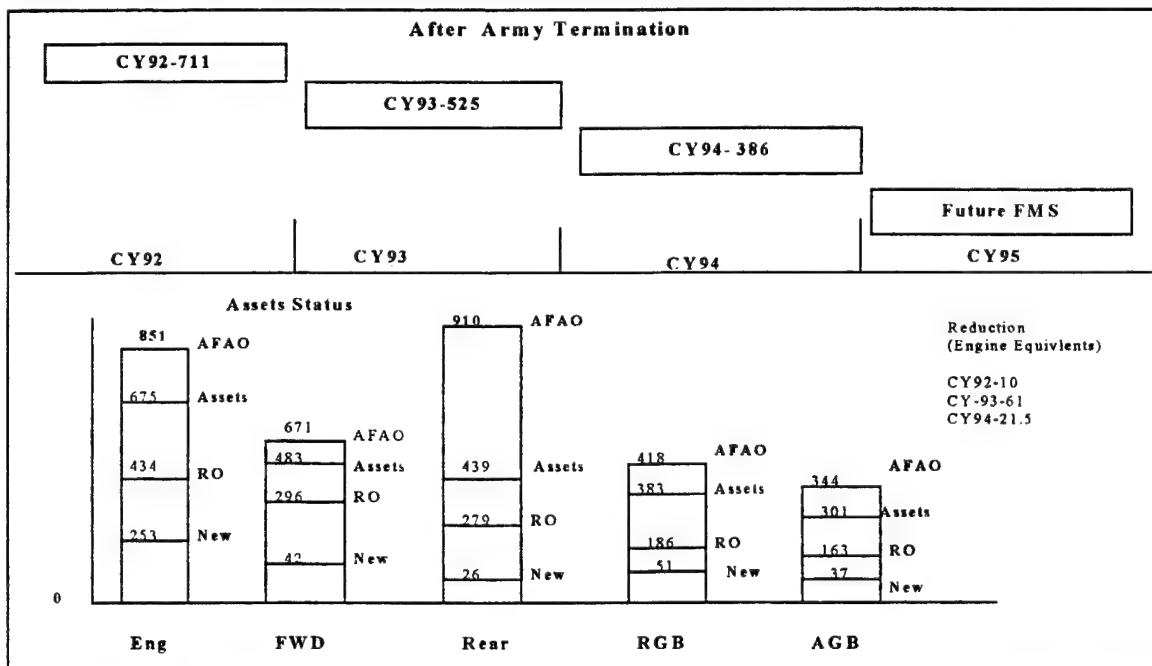


Figure 2. AGT 1500 Engine and Module Delivery Schedule As of December 1992 [Ref. 4, p. 11].

D. PLANNED ACQUISITION STRATEGY TO SUPPORT THE M1A2 PROGRAM

The Army examined the amount of engines in-stock and due-in against projected requirements, both U.S. and FMS, and determined that requirements did not warrant continued new engine production. Even though the FYDP did include the M1A2 Main Battle Tank Upgrade Program, the Army decided not to purchase newly-manufactured engines. TACOM viewed overhauled engines as the most cost-effective option to fulfill requirements for M1A2 propulsion systems. The Army planned to use only ANAD-overhauled engines in the M1A2 program. AlliedSignal interpreted this decision as signaling the end of their ability to remain the producer of the AGT 1500. The determination to eliminate the procurement of new engines was to many, the beginning of the end of the tank engine industrial base. Congress, after receiving many conflicting recommendations regarding acquisition strategy, directed the Office of the Secretary of Defense to commission the Defense Science Board (DSB) to form a blue-ribbon panel. The blue-ribbon panel examined all issues surrounding the preservation of the tank engine industrial base. The following is a listing of the DSB's findings and its recommendations [Ref. 7].

1. Findings

- The Army needs to maintain support engineering, critical sole-source spare parts, and logistics capability at SAEP and retain access to AlliedSignal's unique knowledge and capabilities and company-owned proprietary processes.
- Restructure and down-size SAEP.
- The long-term viability of SAEP depends on AlliedSignal's commercial work. This commercial work is uncertain.
- Dual-use lease procedures are required at AlliedSignal.

- There is minimal and inconclusive data on engine durability; however, it does indicate the need for a continued engine durability improvement program that requires AlliedSignal engineering support.
- There are three options which should be considered (with some possible variations) for the SAEP.

Option A: Current Baseline (Plan to retain a minimal SAEP)

- Current engineering and parts funding streams

Option B: Current Baseline Plus (Plan to retain downsized SAEP)

- Current engineering and parts funding streams
- Some maintenance work transferred from Anniston
- Partial cost-sharing of downsizing
- Engineering funding for evolutionary engine upgrade program

Option C: (Do Not Plan to Retain SAEP)

- Current engineering and parts funding to alternate source

2. Recommendations

- The Task Force recommended that the issue of a significant restructuring and down-sizing effort at the dual-use SAEP continue to be pursued by the Army and AlliedSignal.
- Immediately pursue dual-use leases for the SAEP. A dual-use lease would permit AlliedSignal to continue Government work, while also conducting commercial work at the facility.
- The Army needs to maintain a "critical mass" of support engineering and logistics capability at AlliedSignal for an extended period (even with no production), due to AlliedSignal's unique knowledge and capability. The Army must plan for and fund this effort. The Army should plan to fund design work for potential future upgrades of current engines.

- The Army may need to transfer additional workload to SAEP. AlliedSignal requires this additional workload to maintain a viable overall operation, as well as potential equipment upgrade and or manufacturing capability. The Army must plan to fund certain mission-critical spare parts, such as recuperators, that only AlliedSignal produces.
- The Army should pursue Option B as a reasonable hedge for risk reduction in the near-term and as a step toward a potential long-term solution. This option:
 - Adds costs of approximately \$9M per year for engineering support and \$6M for a one-time downsizing of SAEP (for the Government's share)
 - Assumes \$20M per year of overhaul work transferred from ANAD to SAEP
 - Includes development of dual-use lease arrangements for key elements of the industrial base
 - Includes DoD release of \$17M designated for long lead-time orders (FY94 money)
 - The Army should assess trade-off studies of turbine versus diesel engines for all future heavy vehicles, including replacement of AGT 1500. Additional funding (estimated at \$2-4M/yr.) is required for independent, funded analyses and comparisons to assess the viability of each option.

3. The Army's Position

The Acting Assistant Secretary of the Army, (Research, Development and Acquisition), George E. Dausman, reviewed the blue-ribbon panel's recommendations and stated the Army's position as follows:

- There is neither a requirement for additional new engines, nor any firm prospects for foreign military sales of M1A2 tanks which might generate a requirement for new engines. Development of future heavy tracked vehicles is

not dependent upon the viability of SAEP. There are turbine and diesel engine designs, as well as manufacturing expertise, available within industry that could meet future Army needs.

- The Stratford Army Engine Plant is an unnecessary part of the industrial base infrastructure. It is an overage, overcapacitized, Government-owned facility, ill-suited to what the Army really needs: efficient, low-rate parts production [Ref. 8, p. 1].
- For this reason, the Army viewed with skepticism the blue-ribbon panel's recommendation to provide funding and a transfer of overhaul workload to maintain a "critical mass" of expertise at SAEP. The Army concluded that this option required either a reprioritization of existing programs or additional budget authority. The transfer of workload from the depot increased cost to levels not budgeted for, and raised political opposition.
- The Army did concede that there was a need for continued logistical support from AlliedSignal, namely component supply, and some engineering support for both fielded engines and the depot overhaul program.

The Program Executive Officer, Armored Systems Modernization (PEO, ASM), did not totally concur with Mr. Dausman's memorandum for the following reasons:

- The PEO did agree that there were numerous private enterprises capable of designing and manufacturing turbine engines. His point of contention was that SAEP's proven and qualified process had taken years of tests, field data, and improvements to successfully develop and qualify. Ground combat vehicles have unique requirements that other turbine engine applications do not duplicate. Relocation of the SAEP operation to another site or source would require a costly and time-consuming qualification process. Moving to another site would be like starting with another contractor. The PEO analyzed the reconstitution issue, and concluded affordable new engine production would be paramount in a time of emergency.

- The Army development programs for future heavy tracked vehicles are using the SAEP facilities. The turbine engine currently under consideration for incorporation into the Advanced Field Artillery System and Future Armored Resupply Vehicle (AFAS/ FARV) is benefiting from corporate memory and lessons learned during the AGT 1500 program. The Army will use previous experiences in the SAEP Automotive Test Rig for the AFAS and FARV risk reduction program.
- The Army needs to thoroughly analyze any option that would provide the required tank engine support. A decision to not place additional funds into SAEP is premature. The Army must support the least-cost option. Pursuit of higher-cost options could jeopardized current programs.
- The most important argument regarding the retention of SAEP is the Army's need to maintain readiness of the current tank fleet. In order to meet this goal, an experienced engineering and logistics support staff, as well as an operating and qualified manufacturing capability for critical spare parts, must be retained.

E. FY95 BUDGET

The congressional committees concerned with the defense of our nation, decided to preserve the tank engine industrial base. Congress based its decision on the findings of the Defense Science Board's (DSB) blue-ribbon panel (BRP) commission. The National Defense Authorization Act for Fiscal Year 1994, directed the formation of the BRP. The commission study entitled "Task Force on Tracked Vehicle Industrial Base" recommended several actions to attempt to preserve a tank engine industrial base. The BRP recommended that the Army fund \$20 million of engine overhaul work at the Stratford Army Engine Plant (SAEP), in addition to continuation of funding for necessary spare parts and engineering support. This measure, along with a progressive dual-use leasing arrangement, and an aggressive plant downsizing effort, could permit AlliedSignal to preserve operations at SAEP. The DSB noted that the success of this initiative depends

on the development of commercial business at SAEP. The BRP acknowledged the development of commercial business is uncertain. The direction to the Army from each committee was as follows:

1. House Armed Services Committee (HASC)

The HASC demonstrated a concern that DoD had not adequately addressed the preservation of the tank engine industrial base in its industrial plan. At the time of consideration, the DSB's findings were not available to the HASC. Absent the DSB's findings, the committee believed that DoD may need to take action to preserve the tank engine industrial base in FY95. The committee noted an availability of prior year funds for this purpose. The committee issued a directive to the DoD, instructing the re-programming of funds should the DSB's findings indicate a need for support of the tank engine industrial base beyond 1995.

2. Senate Armed Services Committee (SASC)

The DSB's findings persuaded the SASC of the need to maintain a tank engine manufacturing capability. The SASC directed the obligation of remaining fiscal year 1994 funds, and authorized an additional \$15M in fiscal year 1995 funds for system technical and engineering support, engine durability upgrade efforts, and plant downsizing. The committee authorized \$20M in procurement for engine overhauls at SAEP in FY95, as well as \$15.3M for procurement of spares. The SASC directed the Army to pursue a progressive dual-use leasing arrangement for SAEP. Finally, the SASC permitted the Army to apply other funds, such as production base support, severance, and production continuity, to these efforts.

3. House Appropriations Committee (HAC)

The HAC received the DSB's recommendations and determined \$15M should be appropriated for the Abrams sustainment program. Specifically, the funds were to be used

for both system technical and engineering support, engine durability upgrade efforts, and plant downsizing. It also directed the Army to pursue a progressive dual-use lease for the Stratford Army Engine Plant.

4. The Congressional Conference Committee

The congressional conference agreement included \$35M for the tank engine industrial base program as proposed by the Senate, instead of the \$15M proposed by the House. The conferees agreed to dedicate \$6M of this money for plant downsizing [Ref. 9]. The Army shall use \$9M for system technical support and engine durability upgrade efforts. The Army shall use the remainder of the funds, \$20M, combined with \$12.6M of unobligated funds from the FY 94 program (a total of \$32M), for engine overhaul and upgrade, service life extension, and spare parts. The Army and AlliedSignal shall jointly develop this program. The Army must report to the HAC and SAC on the specific details of any program subsequent to obligating funds. The program developed must illustrate future costs by category for the entire tank engine industrial base effort. Under this agreement the Army cannot use any of the appropriated funds for procurement of new engines.

F. OTHER INDUSTRIAL BASE ISSUES

The following areas are possible alternatives to current business practices; either individually or in a combination of programs, that could help preserve the tank engine industrial base. Although some of them are in the conceptual stage, they have potential for expanding the options for tank engine industrial base preservation. These areas are possible ways for DoD and industry to conduct business in the future, where relatively small production runs and limited funding for programs will be the rule, rather than the exception.

1. Conversion

Conversion is the ability to utilize an item produced for a military purpose for civilian applications. A cursory look at the AGT 1500, reveals what would appear to be a commercial gas turbine engine. A closer examination however, shows only limited similarities to commercial variants currently in production. The AGT 1500 is a stand-alone military vehicular turbine in its own unique niche of size, horsepower, and capability. Therefore, AlliedSignal believes it could retain only a few components for use in either a commercial or another military sector. Closure of the production line could eliminate the tank engine's unique vendor base, manufacturing processes, and related workforce skills. This possibility increases the risk of not having the capability to either re-convert a product, or quickly reconstitute the production line. AlliedSignal admits there is a greater potential for conversion of its military aviation engines to commercial applications. However, AlliedSignal believes it may be difficult to obtain sufficient marketshare to make conversions cost-effective. Due to basic laws of physics and aerodynamics, one size of gas turbine cannot meet all requirements. The investment a manufacturer would need to make to cover the entire spectrum of applications is cost-prohibitive. Therefore, each gas turbine manufacturer selects niches in which to compete, that he feels offers his greatest potential for profit. AlliedSignal views their niche as full, and that future opportunities within the niche will be heavily competed.

AlliedSignal believes that it is absolutely critical to retain a competitive commercial product. AlliedSignal pays rent for the Army tooling that it utilizes in the production of its commercial products. AlliedSignal states that the commercial product produced at SAEP absorbs over 30 percent of the fixed overhead costs that are not passed back to the Army. This aids in keeping the cost of military products as low as possible.

As the military orders decrease in a fixed-capacity plant, AlliedSignal visualizes two options: 1) pass the unit cost increases directly back to the Army; or, 2) force the additional unabsorbed overhead onto the commercial product. If the second option

occurs, it is likely that the commercial base will no longer remain competitive. Should the Army product bear the brunt of cost absorption, the cost of spares or original equipment will become unaffordable. Neither option is acceptable; therefore a smaller capacity facility, properly configured for a cost-efficient production rate, appears to be a viable course of action [Ref. 10, p. 3].

One method for a company to absorb fixed-overhead is to enter other industrial markets. A machine tool capable of making gears or shafts, could likely produce other similar components. AlliedSignal is exploring the possibility of expanding its business base by entering additional markets, such as automotive parts production.

2. Right-sizing of the Production Facility

The U.S. Air Force transferred Stratford Army Engine Plant to the U.S Army in 1976. Upon selecting the turbine as the engine for the M1 tank, the Army and AlliedSignal undertook the effort to upgrade the production facility to a state that would permit the efficient production of the engine. Throughout the 1980's, the Government and AlliedSignal jointly invested money under the DoD Industrial Modernization Incentive Program (IMIP) to modernize the facility. The effort resulted in a plant production capacity of 3,000 engines per month. The total integration included all aspects of manufacturing operations, assembly and test, information support systems, manufacturing equipment, material handling, and employee training [Ref. 10, p. 2]. The Government invested, through the period 1977-1992, \$278.9M. During the same period, AlliedSignal invested \$165.2M. AlliedSignal's sees its challenge as taking a plant currently sized for a capacity of 180 tank engines per month, and re-sizing it to a capacity of 10 tank engines per month. AlliedSignal estimates that the decrease in the number of AGT 1500's produced at SAEP, will increase the future cost of materials by approximately 20 to 30 percent [Ref. 11, p. 8], depending on production levels. Therefore, the rightsizing of the facility must offset the material cost increases by increasing productivity and reducing

facility operating costs. AlliedSignal believes that it can increase productivity by implementing the following changes:

- Focus on fewer manufacturing commodities through make or buy reevaluations.
- Improve management of the shop floor by upgrading the management system.
- Eliminate excess machinery.
- Reconfigure the shop floor to support reduced volume production.
- Reprocess parts to accrue benefits of more capable machines and improved floor layout.
- Retrain work force to upgrade manufacturing related skills.
- Consolidate facilities of SAEP to reduce operating costs.

The implementation of right-sizing SAEP, allows both the DoD and commercial vendor base currently involved with products in production, or a totally independent non-related manufacturing base, to utilize the excess plant capacity. AlliedSignal believes that the unused manufacturing capabilities within SAEP (test cells, laboratories, machine tooling) would provide support to numerous vendors and subcontractors. AlliedSignal also believes that unless the Government relaxes the restriction on commercial use of Government tooling, this action will be ineffective. The Government is attempting to remedy the situation through the implementation of dual-use leases wherever possible.

3. Dual-Use Leases

The Defense Science Board's (DSB) blue-ribbon panel recommended a progressive dual-use lease be implemented at AlliedSignal's facility. The panel recommended that the Government share in the burden of downsizing the production facility. Under this plan, the Government would lease a portion of the reconfigured facility to AlliedSignal. AlliedSignal, meanwhile, would maintain technical skills and manufacturing capabilities at the production facility. Underlying this action is the belief

that AlliedSignal's long-term survival is going to hinge on uncertain future commercial work.

Jacques Gansler, who chaired the DSB's task force, states that the dual-use lease concept is likely to play an increasingly larger role in encouraging defense companies to convert to commercial work, while maintaining the defense base. It is important to note that there has been increasing congressional activity that could pave the way for progressive dual-use leases to become more prominent. The House's FY-95 defense appropriation's bill contains a provision that will allow "industrial facilities of the armed forces to sell articles and services to persons outside of the Department of Defense."

Some who believe that dual-use leases are good for the preservation of the industrial base, cite that federal regulations regarding such arrangements are too prohibitive. The issues which the Government must resolve are: safety, responsibility, cost allocation, and equipment depreciation. Until the Government and industry resolve these issues, dual-use leases will remain viable, but lack the mechanisms needed to make them function properly.

As a GOCO, SAEP is an integral part of the U.S. Army internal defense industrial base. The business base is directly tied to DoD procurement levels of either existing or new product lines. In this case, the commercial business is stable, but contributes a relatively small percentage of standard hours manufactured at the facility. The completion of the current contract will reduce AlliedSignal's business base to the production of other military and commercial engines. Therefore, the goals of a dual-use lease of the SAEP facility are to: 1) provide affordable military and commercial gas turbine engines 2) protect the gas turbine engine technology base, thus providing the capability to improve to existing engines, and to develop new engines 3) sustain fielded SAEP engines, which are rather substantial in number as depicted in the Table 7. As of December 1994, AlliedSignal and TACOM were involved in the negotiation of the dual-use lease of the facility.

4. Breakout

A proposed method of filling production capacity is the return of breakout spares to the Original Equipment Manufacturer (OEM), either by component, cluster of parts, or sub-assembly and assemblies. This could assure OEM quality control at all levels. AlliedSignal would provide subassemblies to the customer with a warranty. Return of breakout generates potentials saving to the customer from: reduced assembly time by Army units, quality control over vendor products, easier incorporation of design improvements (technology insertion), fielded product engineering support, and an OEM warranty [Ref. 10, p. 9].

Military Application	Customer	Engine	Qty.
Huey and Cobra Helicopters	U.S. Army	T53	19,000
Chinook Helicopters	U.S. Army	T55	4,500
Dolphin Helicopter	U.S. Coast Guard	LT101	300
Landing Craft, Air Cushioned (LCAC)	U.S. Navy	TF40B	350
Abrams Tank	U.S. Army & Marines	AGT 1500	11,000

Table 7. Military Engines Produced by AlliedSignal [Ref. 11, p. 4].

5. Return of Depot Workload

The returning of workload previously designated for depots is a very important area of contention between the Government and defense contractors. Normally, depot maintenance workload is mandated by law. Organic facilities perform 60 percent of DoD repair work during peacetime [Ref. 2, p. 12]. This requirement is not usually applied to upgrade and modernization programs. Traditionally, depots perform upgrades and modernization of systems. As the defense budget declines, industry believes DoD must utilize upgrade and modernization programs to sustain critical elements of the industrial base.

Defense contractors' point of contention is the Government depot network has not been shrinking at the same rate as the private industrial base. They believe this uneven shrinkage shifted the bulk of defense work into the hands of the Government. Private industry perceives some depots as aggressively seeking work traditionally performed by contractors. These infringements led industry officials to protest on the basis of not being able to compete on equal terms with depots. Industry attributes the unfairness of the current system of awarding contracts to the Government's: 1) stating the needs and writing the requirements, 2) holding the competition, and 3) selecting the winners [Ref. 12, p. 38]. Costs and overhead are also calculated differently in the Government and private sectors.

Industry feels the Government should be getting out of depot work and putting its workload back into private industry. Private sector industry believes DoD based the rationale for depots on a war with the Soviet Union, that would last several years. During this war, equipment damaged in battle would be returned to depots for repair, and industry would churn out new replacement systems [Ref. 12, p. 38]. Analysts project that the next war will probably be short in duration and will come with warning. This belief fosters the conclusion that the Government no longer needs a robust in-house capability to do repair and overhaul work on its equipment. Industry admits that a shift of depot work to private industry will not solve all the problems of lost defense contracts due to downsizing. Industry does believe increasing the amount of repair and overhaul workload will help preserve its capacity.

It would appear that the Government and DoD are heeding the pleas from private industry. The Army has closed four of its eight major depots in an attempt to eliminate excess depot capacity. The downsizing of depots will allow DoD to maintain a core depot capability. The "core" will provide production capability and preservation of job skills. The retention of a skill's base will allow depots to provide surge capacity in time of crisis. Additionally, the retention of the "core" will permit the training of the depot personnel as expert buyers of services.

G. OPTIONS AVAILABLE TO DoD, CONGRESS AND INDUSTRY

The following three options to sustain the tank engine industrial base are among several that DoD, Congress, and industry have either proposed and are evaluating, or have been evaluated as of this writing:

1. Option One: The Army Should Mothball the Stratford Army Engine Plant After the Last AGT 1500 Gas Turbine is Built and Seek an Alternate Source for Overhaul, Spare Parts, Engineering, and Logistical Support Capabilities

This option is based on the lack of requirements for newly-manufactured tank engines. Army analysis demonstrates that spare engines and depot-overhauled engines are sufficient to meet Army needs until the year 2015, when a new engine will be in service. This includes a complete layaway of SAEP, extensive layoffs, and complete termination of production. This option creates a loss of conceptual, engineering, sole- source component parts, and the management expertise associated with tank engine production. As a result, future re-starts would result in significant shifts in the learning curve. Should mobilization prove necessary in the future, the Army estimates it will take 48 months to bring production rates from 0 to 90 tank engines per month. This closure plan could also be catastrophic to vendors, forcing many either out of business or to shift their business to the commercial sector.

There are gas turbine engine manufacturers capable of producing the AGT 1500. TACOM estimated that it would require \$100M to recompet and develop another source capable of providing the services its desires [Ref. 13, p. 1]. The current technical data is not adequate for competition at the engine or module level. The Army estimates it will require 24 to 36 months, including First Article Test, to implement the alternate source [Ref. 2, p. 17]. In the interim period, the Army would require field support, system technical support, and logistical support. AlliedSignal will have to meet these support requirements. It is conceivable that it would be difficult to find a second source willing to provide such a service. If the current projected workload is insufficient to provide

AlliedSignal with an adequate business base, it is logical to assume another source would probably not receive a satisfactory return on investment and choose to remain out of the field. TACOM's analysis of this option indicated that seeking a second source would be too inefficient, costly, and time-consuming. *Therefore, the Army eliminated this course of action from further consideration.*

2. Option Two: The Army Should Mothball Stratford Army Engine Plant and Move Operations to Another Location Maintaining AlliedSignal as Service Provider

This course of action allows the Army to retain the production of spare parts, and both the engineering and logistical support necessary to maintain the tank fleet's readiness. Moving operations to a COCO facility that has lower overhead rates results in lower product costs. The plan is to phase-out all actual new engine and module production. The smaller facility would maintain the capacity to perform overhaul work, conduct spare parts production, and possibly produce ten new engines per month. The disadvantage is that there would be no facility capable of rapid production of a large number of new engines. The Army would also incur the costs for: the idle facility at SAEP, investment in spare components to cover the interim, requalification of the workforce, and the possible schedule risk associated with the transition.

3. Option Three: The Army Should Complete Production of New AGT 1500 Engines, Establish a Dual-use Lease, and Right-size SAEP

This option allows for the sustainment of SAEP for the near-term and the retention of AlliedSignal engineering, sole-source component parts, logistical support, and reconstitution capability. The overhaul and upgrade of engines consists of taking an engine, overhauling it to specification, and incorporating the latest engineering change proposals. The expense of overhauling an engine is approximately one-sixth the cost of a new engine [Ref. 14, p. 5].

This course of action maintains the industrial base and "core" workforce. The retention of the workforce will ensure the ability of the Army to conduct research and development. This research and development capability will provide engineering improvements to the engine. The improvements will provide the additional engine performance needed to meet the drain of power generated by vehicle weight growth and power requirement increases.

Congress approved funding for this course of action in the FY95 budget. This course of action keeps engine production at current levels until all orders are filled. It allows AlliedSignal to remain in operation, at reduced capacity, and incorporates depot services from Anniston Army Depot as well. In conclusion, this option retains the industrial base, while providing uninterrupted support of the armor force.

III. THE TANK ENGINE INDUSTRIAL BASE WORKFORCE

A. INTRODUCTION

Gas turbine tank engine production requires skills in many disciplines that can be found throughout the gas turbine industry and industry in general. There are some skills that, although not product-unique, are so specific to AGT 1500 production that replacing them would pose some problems. Once lost, a large amount of training time for personnel and their certification would have to be allotted to revive their skills. AlliedSignal is concerned that if the tank engine industrial base were allowed to go "cold", skills normally passed from senior craftsman to their juniors, would be forever lost.

The workforce at SAEP is a diversified group that is totally integrated into the manufacture of both commercial and military gas turbine engines. In the 1980's, the facility evolved from "job shop" production, where similar machines were grouped in a process-oriented fashion, to "group technology" production. The Industrial Resource Enhancement Program (IREP) guided the development of group technology centers, where "ownership" of quality was passed to each individual machine operator. The acquisition of this corporation by AlliedSignal Engines fostered further refinement by introducing just-in-time production cells, which incorporate the continuous improvement process, also known as "Kaizen" [Ref. 15, p. 1]. The objective of this process is to increase response to customer demands, reduce inventory and costs, and increase quality and customer satisfaction. These production cells require multi-process machine operators that have diversified skills. In the downsizing of SAEP, the transfer of skills is of major concern. Failure to properly transfer the necessary skills could lead to reduced product quality and increased costs. Training costs related to the downsizing of the workforce and increasing the flexibility of those workers remaining, will most likely exceed \$1M for the required two-year training program [Ref. 15, p. 1].

B. WORKFORCE ISSUES

The Stratford Army Engine Plant employs approximately 2000 employees who conduct research and develop, design and operate tank engine manufacturing equipment. The major issue affecting the tank engine industrial base workforce is worker training and certification. This section will discuss the workforce structure and the necessary training and certification requirements.

1. Manufacturing and Manufacturing Support

In the manufacturing area there are now approximately 25 classifications involved in the manufacture of turbine parts. In an attempt to increase workforce flexibility, this number reflects a reduction from fifty-one previous classifications. Table 8 lists these classifications and required certifications. The four classifications involved in certifiable processes are:

a. Flame Sprayer and Welder

Both classifications are required to submit test specimens at routine intervals to maintain certification. Analysis of the specimens is performed by the Materials Laboratory and certification issued only after successful completion of testing. Formal and on-the-job training (OJT) is conducted to advance personnel to the required levels. Most flame spray and welding processes involve extensive test specimen control along with exhaustive non-destructive testing (NDT). This is a closed-loop system that requires corrective actions be taken automatically when failures are noted.

b. Spinner

This is a skilled trades classification which requires formal trade school training. A formal apprenticeship program accepts entry-level individuals who then progress toward journeymen and master levels. There is a shortage of this craft in the

marketplace and skill development must be conducted within the organization in order to attain the highest proficiency levels.

c. Non-Destructive Test (NDT) Inspector

This classification participates in the acceptance of critical process yields prescribed by military and commercial specifications. Three levels exist within the classification for operation, leading and training, and interpretation of critical defects. Yearly testing of all inspectors is required to maintain job certification. Processes include X-ray, fluorescent penetrant inspection, magnetic particle inspection, acid etch inspection, ultrasonic inspection, eddy current inspection, and dye check inspection. [Ref. 15, p. 3]

These four classifications are not easily identifiable in the job market and would require extensive training to duplicate. Training times to develop these skills are estimated to exceed four to six months.

Classification	Type	Cert. Req'd	Approx. Pop.
EDM/Drill Operator	Mfg.	No	18
Machine Operator Flexline	Mfg.	No	15
Machine Operator Single Point	Mfg.	No	111
Machine Operator Grinder	Mfg.	No	42
Machine Operator Gear Grinder	Mfg.	No	7
Cutter Grinder	Support	No	7
Tool & Die Maker	Support	No	31
Heat Treater	Mfg.	No	11
Surface Finish Operator	Mfg.	No	11
Polish & Finish Operator	Mfg.	No	23
Flame Sprayer	Mfg.	Yes	3
Plater	Mfg.	No	9
Welder	Mfg.	Yes	25
Sheet Metal	Mfg.	No	56
Spinner	Mfg.	Yes	2
NDT Inspector	Inspec.	Yes	17
Stock Clerk/Material	Support	No	43
Crib Attendant	Support	No	19
Parts Packer	Support	No	24
Plant Clerical	Support	No	21
Material Planner	Support	No	34
Timekeeper	Support	No	4

Table 8. Manufacturing Workforce Classifications [Ref. 15, p. 2].

2. Assembly and Test

AlliedSignal totally integrates the assembly and test areas in all engine programs. The two areas are separate and distinct from each other, but share a goal of meeting customer demands. Due to the depth and scope of the job, training that an employee must undertake to work in both the assembly and test areas is more extensive and comprehensive than that in manufacturing. Senior manufacturing-type employees normally fill assembly and test entry-level positions. AlliedSignal, in an effort to increase flexibility, reduced the number of classifications in this area from twelve to two. These classifications are listed in Table 9.

Classification	Type	Cert. Req'd	Approx. Pop.
Assembly Mechanic	Assy	No	76
Test Mechanic	Test	No	32

Table 9. Assembly and Test Workforce Classifications [Ref. 15, p. 4].

AlliedSignal will retain at SAEP, the machine tools and processes capable of producing the AGT 1500. The difficulty in producing AGT 1500 engines lies within industry's ability to retain necessary skills in its workforce when actual production is not taking place. For a period of time, the necessary skills will reside at SAEP in "core capability." The "core capability" consists of the personnel required to sustain fielded engines while SAEP is at a production rate of zero military engines per month and zero military modules per month. During this period AlliedSignal will retain the minimum capability to produce military engines and modules. Unfortunately, these skills will most likely disappear with the passage of time. AlliedSignal identified the critical labor skills at SAEP most at risk of loss as follows:

- * Spin Lathe Operator
- * Fusion Welder
- * Gear Cutter
- * Flame Spray
- * Radiology Technician
- * Electron Beam Welder
- * Laser Operator
- * Operator Laser Operator
- * Electron Beam Welder

C. WORKFORCE ANALYSIS

This section will analyze the potential effects on the tank engine industrial base workforce of the two options remaining available to DoD, Congress and industry.

1. Option One: The Army Should Mothball Stratford Army Engine Plant and Move Operations to an Alternate Location, Keeping AlliedSignal as the Service Provider

As stated earlier, this course of action allows the Army to retain the production, engineering, logistical and spare parts support necessary to maintain tank fleet readiness. The Army anticipates that, by moving operations to another location, the expense of the support that it desires from AlliedSignal would decrease. The Army makes that conclusion based on the assumption that the new facility would be contractor-owned and operated. The Army also assumes that the facility's location will be in a geographic region where labor and tax rates are relatively lower.

This plan includes a complete layaway of SAEP, extensive employee layoffs and termination of tank engine production. TACOM defines layaway as the process of retaining and storing industrial facilities that are no longer required to support current production. DoD could reactivate these facilities at a future date, should the need for continued production arise [Ref. 16, p. 48].

AlliedSignal estimated that 550 employees would be necessary to maintain the "core capability" to provide the services that the Army desires [Ref. 11, p. 12]. This would mean that layoffs of approximately 1500 personnel would have to take place. The number of layoffs could increase, if those personnel chosen to remain did not elect to relocate to the new production facility. The Government is contractually liable for human resource separation costs at SAEP. Human resource costs are defined as all costs associated with separation of contractor personnel and include: separation pay, health care, supplemental benefits, group insurance, pensions, and dental care [Ref. 16, p. 48].

Should the government choose to implement this option, it can expect to pay \$12M in human resource separation costs [Ref. 17, p. 22].

a. Advantages

From a workforce standpoint, the large expense associated with terminating the majority of the tank engine workforce has few advantages. The lack of a requirement for newly-manufactured tank engines and the limited amount of engine overhaul work, does not provide justification to support a workforce sized to produce new engines. This option does afford the opportunity for the retention of at least some of the current workforce's knowledge and potentially lessens the impact on the re-learning curve.

b. Disadvantages

Because of the long training time associated with certain skills, the closure of SAEP would force those employees who were unwilling to relocate, to seek employment elsewhere, thus losing their expertise. Fortunately, AlliedSignal has enacted diversified training for its employees. This training allows employees either not selected for retention or unwilling to relocate, to actively compete within their job specialty elsewhere in the gas turbine engine industry.

This option will also effect the senior engineers and managers at SAEP. This is critical to AlliedSignal, since the AGT 1500 has some unique design and operating characteristics. The importance of senior engineering knowledge was exemplified during the Gulf War. These experienced personnel deployed to the battlefield to assist the Army with logistical and engineering support of their engines. The possibility of the loss of this knowledge base could have a significant impact on future designs of gas turbine engines for military applications, as well as upgrades to the existing AGT 1500.

Both options that the Army is considering call for the cessation of actual production of new engines. The Army will retain the capability to produce at least ten

new engines per month at the SAEP or new facility. The loss of actual production will mean that a significant shift in the learning curve will take place. The learning curve reflects an increase in production efficiency and quality that generally leads to cost reduction of the item. Improvement in the learning curve is a result of workers and managers gaining familiarity with production processes. As the workforce becomes more familiar with the processes, they are more capable of identifying errors and rapidly implementing corrective actions. The amount of the shift will be dependent upon the ability to rehire those employees lost during the downsizing. As time passes, it must be anticipated that some employees will be forever lost due to retirement or unwillingness to leave their current employment.

c. Conclusions for Option One

The effects of total production termination, layaway of SAEP and moving of AlliedSignal to another location, are potentially the most devastating to the tank engine industrial base. The loss of at least 1500 employees from production-level through management-level will be felt in the loss of personnel skills, qualifications and experience. A break in production will result in both a loss of quality in the engine produced and decreased efficiency of production. The amount of time to retrain a "cold" base workforce capable of producing new engines is seven months for unskilled laborers and 14 months for skilled laborers [Ref. 13, p. 2]. Even though the "core capabilities" are retained during relocation, the Army would experience a disruption in services as operations are established at the new facility.

2. Option Two: The Army Should Complete Production of New AGT 1500 Engines, Establish a Dual-use Lease and Right-size SAEP

This option permits sustainment of SAEP, for at least the near term, and provides the Army the ability to retain AlliedSignal's production, engineering, and logistical support

capabilities. This option also keeps the workforce at a familiar location, thus minimizing disruption of services provided to the military.

a. Advantages

The advantage of maintaining the “core capabilities” at SAEP is that there is no immediate loss of either production job skills or the engineering and support knowledge base. The complete retention of the “core capabilities” enables the contractor to have a knowledge and skill base that will greatly improve the quality of the training that new employees would receive. By not relocating the production facility and the workforce, the contractor will not have to retrain the workforce and requalify his production processes. The Army estimates that this action will save \$7.7M (FY 95 & FY 96) [Ref. 17, p. 17].

b. Disadvantages

As with Option One, the loss of skilled workers could be critical if full regeneration of the production line became necessary. The training and certification of a workforce whose size is large enough to produce 90 engines per month, would take approximately eighteen months. Should reconstitution prove necessary, the inexperience of the workforce would likely hamper efficiency and quality of the engine during the initial stages of production. This projected initial lack of efficiency and quality will most likely be accompanied by higher engine costs. This observation is also applicable to Option One.

The high overhead rates at SAEP, which are attributed mainly to its geographic location, could eventually lead to a loss of engineering capabilities. Should the amount of Government workload be insufficient, AlliedSignal might have to eliminate engineering services for the AGT 1500 [Ref. 17, p. 18].

c. Conclusion for Option Two

This option provides the best opportunity to retain the production and support workforce base. This retention of "core capabilities" provides the Army with the ability to maintain an industrial base that could be regenerated in a time of emergency. This course of action minimizes the risk of disrupting the flow of services currently provided by AlliedSignal and retains the ability to regenerate the production line. From a workforce perspective it is the least-cost option.

D. SUMMARY

Option Two provides the best potential to preserve the tank engine industrial base. Option Two allows the AGT 1500 "core capabilities" to remain intact. There will be a loss of a large portion of the skilled workforce. However, there is a skeleton of a workforce that will remain at the facility. This remaining workforce, or "core", will provide the support that the Army deems necessary to maintain its tank fleet's engines. The "core" will be able to produce at least ten engines per month and will provide continuity and expertise should full regeneration of the production line be required in a time of emergency. This option provides for the continued improvement of the engine, as well as reducing the Army's risk of losing engine maintenance capability.

Although Option One has many of the advantages of Option Two, it does have several important differences. This relocation of the facility increases the amount of risk to the Army. The movement to a new facility would create a disruption of spare parts production and support, thus jeopardizing tank fleet readiness. It would also add costs of recertification and workforce training. A new site would also have to meet the requirement of being large enough to support possible engine production. This additional space would most likely remain idle until circumstances required its use. The SAEP, which will be idle under this scenario, has the floor space to produce thousands of engines.

In conclusion, terminating production will have a damaging effect on the skills and knowledge of the tank engine industrial base. The lack of a requirement for new engine

production drives the Army to find an alternative that will provide logistical support, engine overhaul and upgrade capabilities, and emergency regeneration of the tank engine production line. The retention of a small, but competent and experienced workforce, will provide the Army the support it requires to maintain its tank fleet and tank engine industrial base.

IV. COSTS

A. INTRODUCTION

With the decline in defense spending, the costs of implementing any option is of paramount concern to the Army. This chapter will analyze the costs involved in executing the two options and their effects on preserving the tank engine industrial base.

B. COST ANALYSIS FACTORS

From 1992 to present, TACOM conducted in-depth analysis of costs related to the preservation of the tank engine industrial base. The scope of these studies included options to: 1) layaway the industrial facilities at SAEP for future use, 2) maintaining new engine production capacity; while retaining both critical equipment and an experienced workforce, 3) conduct overhaul and upgrade of existing engines. TACOM and AlliedSignal developed the cost estimates utilized in the analysis.

1. Assumptions

During the formulation of these courses of action, TACOM made some basic assumptions that have bearing on the costs presented. They are:

- AlliedSignal will support the Army's AGT 1500 support requirements.
- AlliedSignal's support capability is vital to the Abrams tank fleet's readiness and engine overhaul program.
- EPA liability applies to either option but cost impact is varied due to timing of implementation.
- New engine and module manufacturing capability existence applies to either option.

2. Other Cost Considerations

When presenting the costs of the overhauled engine and sole source parts, a number of variables impact on the price of the services charged to the Army. TACOM must take into account cost factors such as inflation, workforce training, engineering and logistical support, spare parts, and warranty considerations.

3. Evaluating Factors

TACOM utilized the following cost factors in the analysis of the two options to preserve the tank engine industrial base: facility projects, equipment removal, environmental clean-up, human resources, closure penalty, program management, maintenance and caretaking of SAEP, AlliedSignal engineering and logistical services, and AlliedSignal spare parts production.

a. Restoration Projects

Restoration projects include the costs of building and grounds upkeep and maintenance. It includes actions such as roof repair, and upgrade and replacement of equipment.

b. Equipment Removal

This cost includes the planning, disconnecting, packaging, crating, handling and shipping of Government-owned equipment.

c. Human Resource Costs

As discussed in the previous chapter, human resource costs involve the payment of separation pay, health care benefits, supplemental benefits, insurances, pension plans and dental care.

d. Closure Penalty

This cost is a contractual obligation incurred by the Government for the reduction in production rates. Federal Acquisition Regulation (FAR) 52.249-2 Termination for Convenience of the Government and FAR 52.249.9 Default, provide guidance to agencies in determining and calculating termination costs.

e. Program Management Costs

Program management costs are derived from requirements to coordinate both internal and external office functions. It also includes cost tracking of inventory, and preparation of reports to maintain schedules and budgets [Ref. 16, p. 65].

f. Maintenance and Caretaking Costs

These costs include: utilities, maintenance, security, fire protection, and the staff necessary to maintain the facility once it has been shutdown.

g. AlliedSignal Engineering and Logistical Services

The costs associated with engineering and logistical service includes the amount of funding that must support AlliedSignal's technical base. The annual system technical program incorporates the engine durability improvement program, both depot and field support, and support of the technical manuals for the engine. The engineering support to production encompasses a service life extension program and spare parts manufacturing.

h. Environmental Clean-up

Environmental clean-up costs are associated with the preparation of the facilities and grounds of SAEP. Before SAEP could be sold to a prospective buyer it must meet all EPA standards for toxic waste removal and disposal.

C. COST ANALYSIS

This section provides an analysis of the potential costs of the two options that TACOM is currently recommending to preserve the tank engine industrial base.

1. Option One: AlliedSignal Continues to Provide Services, but Relocates to a Different Facility

In determining the costs associated with the implementation of this option, TACOM made the following assumptions:

- The Government will not pay relocation costs for AlliedSignal's commercial applications.
- The Government will accept liability for the relocation and requalification of recuperator production capability, as well other related Government costs.
- Relocation of the facility will necessitate a spare part build ahead program.

TACOM analyzed the option to terminate production and layaway SAEP with the understanding that support of the AGT 1500 will remain necessary to the year 2015. At the end of this period the Army expects to field another tank engine. Cost of the total layaway at SAEP is found in Table 10. As displayed in Table 10, the total closure cost is estimated to be \$757.3M. The majority of the costs associated with implementing this option are derived from both engineering and logistical support, and spare parts production procured from AlliedSignal.

Option 1 ROM Closure Cost-\$M ESC						
	FY95	FY 96	FY97-99	FY00-15	AVG FY99- FY16	Total
Implementation Cost						
Relocation	0	0	5.5	0	0	5.2
Closure	0	4.1	3.8	0	0	7.9
Build Ahead	0	13	13.4	0	0	26.4
Program Mgmt	0	0	1.1	0	0	1.1
Subtotal	0	17.1	23.8	0	0	40.6
Non-Recurring Costs						
Downsizing	6	0	0	0	0	6
Restoration	2.5	2.4	0	0	0	5
Program Mgmt	0.5	0.5	0	0	0	1
Environmental*	0	8.8	9.1	0	0	17.9
Contract Liability	20	0	0	0	0	20
SLE Program	10	12.5	10	0	0	32.5
Subtotal	39.1	24.2	19.1	0	0	82.4
Recurring Costs						
Maintenance	3	0	0	0	0	3
Caretaker	0	0	3.5	24.8	1.6	28.3
Sys. Tech Spt.	10	6	19.6	142.6	8.7	178.2
Spare Parts	26.2	21.3	29.7	347.6	20.2	424.8
Subtotal	39.2	27.3	52.8	616	30.4	634.3
Total	39.2	68.5	105.6	616	30.4	757.3
*Does Not Include Long Term Environmental Remediation-\$422M ESC						

Table 10. AGT 1500 Industrial Base, Cost of Option One, As of January 18, 1995, [Ref. 19, p. 4].

a. Advantages

The advantage of this option is that production and support of the AGT 1500 does not require a GOCO facility. A modern COCO facility, properly configured, can produce parts more efficiently and with less overhead than parts produced at SAEP. TACOM estimates that by adopting this course of action the Army will save approximately \$388M over the next 20 years [Ref. 17, p. 29].

b. Disadvantages

From a cost standpoint, it is very expensive to close the SAEP. The Army must invest \$74.9M in a spare part build-ahead program. This program will provide the spare parts necessary to meet Army requirements during the period of facility relocation.

The Army would also be responsible for paying \$14.2M in FY95 and FY 96, for requalification of production processes and retraining of the workforce [Ref. 17, p. 25]. Placing SAEP back into operation after a one-year layaway would cost the Army \$42M. This option also has the greatest potential for the largest EPA cost. It will cost the Army more to conduct EPA projects that will bring the SAEP facility and its grounds to required standards.

c. Conclusions for Option One

This course of action becomes less costly over time. The data presented are estimates, based on current policies of DoD, AlliedSignal, and Congress. The proof of the assumption that a COCO facility is less costly to run, and that anticipated savings will be passed back to the Army product, is a major factor. There is an additional risk associated with this course of action. The costs of closure are scheduled to be spread over FY 95 and FY 96. Should the requested amount of funding not be appropriated, the Army and AlliedSignal may be forced to execute a less than adequate closure process, potentially leading to increased future restart costs [Ref. 16, p. 69].

2. Option Two: The Army Right-sizes SAEP, Institutes a Dual-use Lease, With AlliedSignal Providing Production Capacity and both Logistical and Engineering Support

In determining the costs associated with the implementation of this option, TACOM made the following assumptions:

- The Army and AlliedSignal will establish a dual-use lease.
- The Army will incur idle facility costs for buildings no longer in use.
- AlliedSignal will absorb all leased facility costs.
- The cost to reorganize and realign the facility will be reflected in AlliedSignal's overhead rate.

This option, as with Option One, includes a one-time downsizing cost of \$6M incurred by the Army. The main difference that this option provides is production capacity and retention of a "core" workforce. This would permit more rapid reconstitution of the production line in time of emergency. The cost of implementing this option is reflected in Table 11.

As displayed in Table 11, the total cost of this option is estimated to be \$1143.4M. The majority of the costs associated with implementing this option are derived from new production spare parts procured from AlliedSignal.

a. Advantages

From a cost perspective, this option provides the Army an opportunity to avoid a \$7.7M charge in FY 95 and FY 96 for the retraining and requalification of the workforce and manufacturing processes. Additionally, this option has the potential of being least in cost for EPA projects. The Army's continued utilization of some of facilities at SAEP, will reduce the amount of area required to be cleaned to EPA standards.

b. Disadvantages

This option requires an up-front investment of \$41.7M to prepare the facility and related operations for reduced capacity production [Ref. 17, p. 22]. The anticipated high overhead rate, will drive the cost of spares substantially higher than those in Option One. The increased cost of spare parts and the reduced Government workload, may lead AlliedSignal to terminate its engineering base.

Option 1 ROM Closure Cost-\$M ESC						
	FY95	FY 96	FY97-99	FY00-15	AVG FY99- FY16	Total
Implementation Cost						
Relocation	0	0	0	0	0	0
Closure	0	0	0	0	0	0
Build Ahead	0	0	0	0	0	0
Program Mgmt	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0
Non-Recurring Costs						
Downsizing	6	0	0	0	0	6
Restoration	2.5	2.4	0	0	0	5
Program Mgmt	0.5	0.5	0	0	0	1
Environmental*	0	8.8	9.1	0	0	17.9
Contract Liability	20	0	0	0	0	20
SLE Program	10	12.5	10	0	0	32.5
Subtotal	39.1	24.2	19.1	0	0	82.4
Recurring Costs						
Maintenance	3	6.9	13.9	98.7	6	121.5
Caretaker	0	0	6.9	49.3	3	56.2
Sys. Tech Spt.	10	6	19.6	142.6	8.7	178.2
Spare Parts	26.2	21.3	69	588.7	35.8	705.1
Subtotal	39.2	33.2	109.3	879.3	63.6	1061
Total	78.3	67.4	128.4	879.3	63.6	1143.4
*Does Not Include Long Term Environmental Remediation-\$422M ESC						

Table 11. AGT 1500 Industrial Base, Cost of Option Two, As of January 18, 1995, [Ref. 19, p. 5]

c. Conclusions for Option Two

The costs associated with this option hinge on the belief that although SAEP would be downsized, its overhead rates will be exceedingly high. The high overhead rate will be passed back to the Army in the form of higher costs for spare parts and logistical support. While this option is less expensive to initially implement, it does have the greatest potential for cost growth.

D. SUMMARY

From a cost perspective, Option Two provides the most cost-effective course of action for the Army to pursue. This option provides both the engineering and logistical support the Army requires. It also provides the production capacity that the Army desires for contingency situations and FMS. Option One is the most costly of the two options under consideration. As stated earlier, if the Army selects Option Two, operations will remain at SAEP until sufficient spares are produced. During this period the Army will have the opportunity to verify cost estimates presented in Option One. Should actual costs prove that continued utilization of SAEP is the most cost-efficient course of action, then the Army could opt to reverse its decision to relocate the facility.

V. MOBILIZATION AND SPARE PARTS

A. INTRODUCTION

The chapter will explore the ramifications of the two options under consideration to preserve the tank engine industrial base with respect to mobilization and spare parts issues. As military operating budgets continue to shrink, the Armed Services must make difficult decisions on how to spend limited funds. Our military planners must see into the future and determine what the military needs for equipment will be in 20 to 30 years. They must use this vision to analyze the risks associated with allowing certain defense industrial bases to go "cold." Proper precautions and planning for mobilization and surge capacity of the defense industrial base can reduce the risk of being caught "shorthanded" in the next conflict. The issues of mobilization and surge planning are analogous for DoD systems. A thesis on a related topic, "*A Comparative Analysis of Options For Preserving The Tank Industrial Base*," written by Juan J. Hernandez effectively defines these topics. Therefore, this thesis will not redefine the policies and procedures for DoD planning for industrial base mobilization and surge capacity in great detail.

The defense planners must take into consideration the guidance concerning reconstitution of the defense industrial base as set forth in the National Military Strategy [Ref. 21, p. 24]. The document describes reconstitution as: laying away infrastructure, stockpiling critical materials, protecting the defense industrial base, sustaining a cadre of quality leaders, and investing in basic science and high-payoff technologies.

B. MOBILIZATION OVERVIEW

The issue of mobilization of the industrial base to provide the weaponry necessary to conduct warfare has fundamentally changed from the 1940's to present day. During World War II, the civilian industrial capacity was largely converted over to provide massive outputs of war materials. This rapid conversion of the industrial base was part of our national defensive strategy throughout the Cold War. President Reagan changed the

paradigm by stating mobilization was only a supporting capability for deterrence and the flexible response strategy [Ref. 16, p. 108]. The demise of the Soviet Union and the United States' increased role in humanitarian missions and peace-keeping operations have increased the need for a flexible defense industrial base. The maintaining of a defense industrial base will provide the foundation for future weapon systems development.

Jacques Gansler, who headed the Defense Science Board's blue-ribbon panel that studied the Tracked Vehicle Industrial Base, believes the issue here is not mobilization, but the development of future systems. He asserts that DoD must concern itself with preserving the capability to conduct research and development and potential production in areas that are defense-unique [Ref. 20, p. 26]. This belief supports the National Military Strategy's guidance, that it is crucial to maintain the research and development capabilities to provide product improvements, modernization, and technological innovation to support our forces. The loss of the engineering support provided by AlliedSignal could negatively impact the Army's development of future gas turbine engines. Whatever the justification for the preservation of a critical component of the industrial base, mobilization planning consists of a variety of activities.

1. The Mobilization Process

The planning for industrial preparedness is initiated once the Defense Guidance is received from the Secretary of Defense. The Joint Staff receives from the Unified and Specified Commanders, a list of critical weapon systems and components. This input is used to develop a DoD prioritized listing of critical weapon systems and components [Ref. 16, p. 109]. Each military service then develops a list of respective critical weapon systems and components. The services' selections are then incorporated into the Industrial Preparedness Planning List (IPPL).

a. *Industrial Preparedness Planning List*

The IPPL is divided into two sections. The first section includes major end items such as tanks, and the second section includes major components such as tank engines. Each service must submit its IPPL to the Deputy Undersecretary of Defense for Industrial and International Programs and the Defense Logistics Agency (DLA). These agencies then develop their respective IPPLs [Ref.14, p. 109]. The listed items are then placed within the surge and mobilization plans.

b. *Objectives of Mobilization Planning*

The objectives of mobilization planning are to plan the total requirement for post-mobilization day production of the critical weapon systems and items listed in the IPPL and identify planned emergency producers. Planning is accomplished by utilizing one of the following methods: 1) DD Form 1519, 2) Data Item Description 3) special studies and 4) Direct Industrial Base Plan (DIBP) [Ref. 16, p. 110]. An analysis of these methods used to accomplish the mobilization objective is contained in Hernandez's thesis.

c. *Objectives of Surge Planning*

Surge planning is an assessment of the costs and efforts related to increasing peacetime production rates of a contractor. Until 1993, the plan was for AlliedSignal to surge from a production rate of 30 engines per month to 90 engines per month. Each Service updates its surge production plan annually to allow for changes in requirements [Ref. 16, p. 112].

Preserving the capability to expand of air, ground, and maritime forces requires foresight and political support to layaway infrastructure, stockpile critical materials, protect the defense industrial base. A key element in responding to this challenge is Graduated Mobilization Response (GMR). This national process integrates actions to increase our emergency preparedness posture in response to crisis. These

actions are implemented to reduce the amount of lead time associated with responding to a national emergency [Ref. 21, p. 25].

With the lack of a current superpower foe, it would appear that the United States will not have a near term requirement to mobilize its industrial base to the magnitude required to win World War II. The possibility of U.S. participation in a smaller conflict, such as the Gulf War, may require limited surge production of certain critical items.

C. SPARE ENGINE AND SPARE PARTS OVERVIEW

The availability of spare parts is a major factor in tank fleet readiness. During the Gulf War, the Army removed numerous items from the assembly floor to support its tank fleet [Ref. 16, p. 114]. This raised serious questions concerning the adequacy of Army reserve stock levels in a time of war. Currently, the Army maintains 350 complete M1 tank engines in its war reserve. The modular design of the engine allows for the removal of an unserviceable component. Once an engine fails, unit-level maintenance removes the bad module and installs a new module. For this reason, the Army has a varying number of modules in the system being repaired and replaced in inventory. The Army believes that it has a sufficient amount of war reserve engines and modules to support its tank fleet in time of crisis.

Thus, the Army opted to cease production of new engines and modules. The Army and AlliedSignal developed the two courses of action with regard to adequate spare parts production and both engineering and logistical support.

D. ANALYSIS

This section will analyze the two options in regard to surge production and spare parts production. There are factors that affect mobilization planning with equal weight. Figure 3 illustrates the re-start schedule from a cold base. This timeline is pertinent to either option as they both permit the production base to go "cold." Additionally, the loss

of actual production will result in the disappearance of vendors whose services are no longer needed, or who cannot remain profitable due to reduced workload.

The loss of vendors is a problem that AlliedSignal has dealt with throughout its production of the AGT 1500. From 1993 to 1994, 26 suppliers of AGT 1500 parts have either consolidated or closed their facilities. An example of the impact that a vendor's leaving the marketplace has on a production is as follows:

A company that provided a part called a swirler notified AlliedSignal that it was going out of business. AlliedSignal found another capable source to provide the part. AlliedSignal invested \$50,000 to tool the new source and an undetermined amount of money to qualify the source's processes. A year after selection, the source is continuing to produce unacceptable rates of scrap and rework. Consequently, deliveries are normally one to two months behind schedule. As the vendor struggles to rectify his problems, the cost of a swirler has increased from \$800 per unit to \$1,500 [Ref. 22, p. 2].

1. Option One: The Army Should Retain AlliedSignal as the Contractor, Mothball SAEP in Three Years, and Relocate to Another Facility

As mentioned earlier, this option includes complete layaway of SAEP, extensive layoff of the workforce, selling of equipment and relocation of the facility.

a. Surge Requirements

This option provides the Army a surge capacity of 10 engines per month. With operations remaining at SAEP, the equipment and test facilities, and workforce will be present for contingency operations. Should it prove cost-ineffective to remain at SAEP, the operation will in all likelihood move to Phoenix, Arizona. Phoenix is where AlliedSignal's main headquarters is located. The Army would then have to evaluate the cost of moving enough equipment from SAEP to the new facility to retain production capacity. If it proves not cost-effective to move the equipment, then the Army would

probably opt to retain zero capacity to produce new tank engines and modules. In the event that emergency conditions warrant the reconstitution of the production line, the Army would have to locate a facility large enough to handle production requirements. Reconstitution of the tank engine production line will take 36-48 months. This time will vary depending on how long the production line has been "cold." The longer the break in production lasts, the more time and money it will cost the Army to reconstitute the production line. These increases are derived from training and certification of the workforce and manufacturing processes required to achieve newly-manufactured engines.

b. Spare Parts

With regard to spare parts, this option provides the least cost to the Army for spare parts produced by AlliedSignal. Currently, AlliedSignal produces 16 sole-source critical parts for the AGT 1500. These options will provide the capacity to produce 150 recuperators per month [Ref. 23, p. 6]. TACOM expects Option One to benefit from the anticipated lower overhead of a COCO facility. This reduced overhead will make spare parts more affordable and retain the engineering support base. The disadvantage provided by this option is the amount of spares that the Army must initially stockpile to provide support during the move. TACOM designed this spare parts build-ahead program to reduce the risk of not having enough spare parts to meet engine overhaul and field support requirements.

2. Option Two: The Army Should Retain AlliedSignal as Contractor, Establish a Dual-use Lease and Downsize SAEP

This option includes downsizing SAEP's IPE 68 percent, active floor space 40 percent and active structures 41 percent. The Army will establish a dual-use lease with AlliedSignal while retaining capacity to produce 10 AGT 1500's and 25 commercial engines per month [Ref. 23, p. 9].

a. *Surge Requirements*

The retention of a downsized SAEP affords the Army the best opportunity to reconstitute the production line. Granted, analysis shows that it will take the same amount of time to reestablish the production line as in Option One. The key difference is that the floor space necessary to surge to 10 engines per month will always be readily available. If the Army mothballs all IPE located at SAEP, AlliedSignal will have the equipment necessary to provide increased surge production capabilities.

b. *Spare Parts*

Option Two provides the advantage of keeping the production processes of spare parts intact. By retaining the production facility, the Army will not have to recertify the processes and train a workforce. This option reduces the risk associated with a break in the production of spare parts. TACOM predicts that remaining at SAEP will cost the Army more in the long run for its spare parts. It remains to be seen if the downsizing of SAEP will reduce overhead rates low enough to make spares affordable.

E. SUMMARY

From a mobilization and spare parts perspective, Option Two provides the greatest advantage to the Army. By selecting this option, the Army reduces the risk of allowing the tank engine production line to "cold." Leaving the facility at SAEP provides AlliedSignal the ability to keep the crucial production process of the recuperator uninterrupted. Additionally, the capacity to produce at least 10 newly-manufactured engines per month provides some insurance for the Army to meet future demand requirements. Option One does not provide the ability to reconstitute the production line; unless the Army decides to move the aging equipment from SAEP. This option has the greatest long-term cost saving potential for spare parts production. While it is the least costly of the two options, Option One is the action that most threatens the tank fleet readiness.

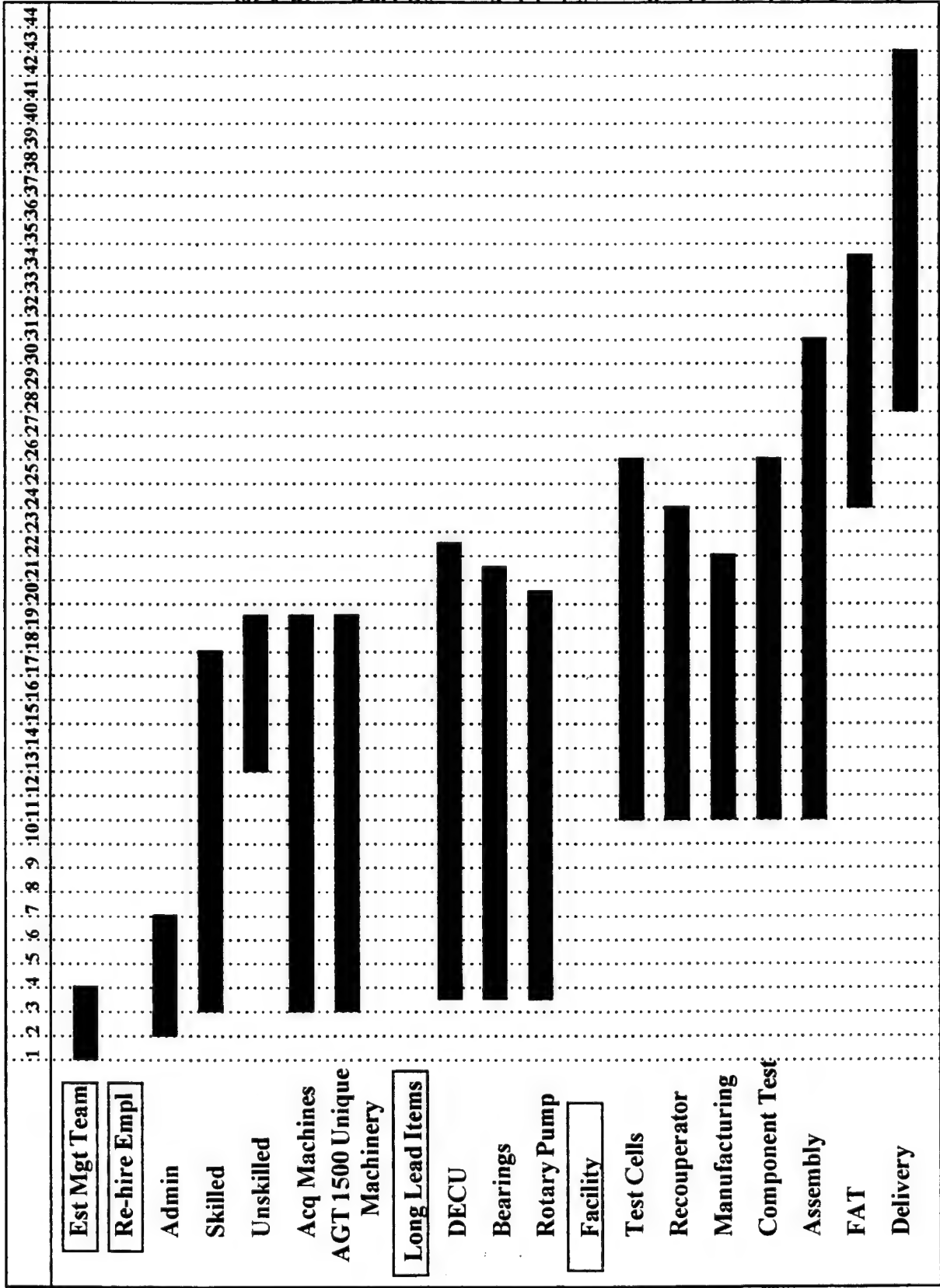


Figure 3. Production Line Restart Schedule From a "Cold" Base, [Ref. 18].

VI. OPERATIONAL EFFECTIVENESS CONSIDERATIONS

A. INTRODUCTION

This chapter will discuss operational effectiveness factors as they relate to the two options under consideration to preserve the tank engine industrial base. The analysis will focus on both engine performance and durability risks associated with the closure of the tank engine production line. This section will introduce the three alternatives that will meet the tank fleet's engine requirements. These alternatives are: newly-manufactured engines, remanufactured engines, and overhauled engines.

- **New Engines:** Engines manufactured by AlliedSignal to specifications and standards maintained in the technical data package (TDP). The manufacturer assembles the engine with all new parts and tests them to specific performance parameters. Newly-manufactured engines come with a durability warranty and cost approximately \$500,000.
- **Overhauled Engines:** Engines restored to a completely serviceable condition as prescribed by maintenance serviceability standards included in a depot maintenance work requirement (DMWR). Overhauled engine work follows an "inspect and repair only as necessary" philosophy. Depots normally accomplish overhaul work. Overhauled engines are tested to performance parameters and as many parts from the engine are reused and reclaimed to keep costs as low as possible. Approximate cost of an overhauled engine is \$60,000. TACOM and AlliedSignal are negotiating durability warranties for overhauled engines.
- **Remanufactured Engines:** There is no agreed upon definition between TACOM and AlliedSignal as to level of repair of a remanufactured engine. Preliminary indications are that a remanufactured engine will be like a newly-manufactured engine, in both performance and durability. AlliedSignal will use a developed process to employ a mixture of new and used components that

have been returned to original tolerances. A remanufactured engine will carry a durability warranty. Approximate cost of a remanufactured engine is \$260,000.

B. BACKGROUND

The Army's decision to utilize Army depot overhauled AGT 1500 engines raised concerns at AlliedSignal regarding engine durability and performance. This concern was founded on the M1 tank being originally fielded with a gross vehicle weight of 60 tons. Currently, the M1A2 is expected to weigh 70 tons. From 1980 to present day, the AGT 1500 has had no performance improvements incorporated within its design. The original performance specifications have degraded 30 percent due to: increased vehicle weight, and addition of a nuclear, biological and chemical protection system [Ref. 10, p. 9]. AlliedSignal also contended that engines overhauled at ANAD were not meeting engine durability standards. AlliedSignal proposed to the Army that it should continue the purchase of newly-manufactured engines or remanufactured engines to meet its M1A2 Upgrade Program's objectives. This perceived degradation of both engine performance and durability led the armor community to review these allegations.

1. Performance Risk

a. Mobility Effects On Tank Survivability

The Mounted Warfare Battlespace Laboratory at Fort Knox Kentucky, employed an independent firm to perform modeling and simulation to compare the performance of new engines versus overhauled engines. The study compared an engine at 100 percent capability against an engine that's performance is rated at 90 percent of original performance specification. The 90 percent standard is the performance specification that an overhauled engine is required to meet. The model illustrated that the

largest difference in engine performance was two miles per hour on soft soil [Ref. 24, p. 1].

A tank force was modeled to assess what impact the difference in speeds would have on tank survivability. The model was event sequenced, utilizing a European tactical scenario. The result of the simulation was that there was no discernible statistical difference between the two engines.

b. Engine Comparison Against Requirement

A comparison of engine performance was completed by General Dynamics Land Systems, the prime contractor for the M1 tank. The model compared the 100 percent performance capability engine to a 90 percent performance capable engine. The study showed that the 100 percent engine did out-perform the 90 percent engine. Unfortunately, neither engine met the performance specifications set forth for the M1A1E2 (M1A2) acquisition program.

Conclusions drawn from the modeling were: 1) the difference in the tank speeds does not provide a statistically discernible increase in tank survivability, 2) the small difference in tank speed infers that engines overhauled at ANAD provide 98 percent of required horsepower 3) Neither overhauled nor newly-manufactured engines met the performance specifications required by the M1A2 acquisition program. Even though the overhauled engines were actually very close to meeting the performance of a 100 percent engine, performance was lacking. It appeared AlliedSignal would have to incorporate improvements into the engine's design to achieve required performance objectives.

2. Durability Risk

The user's requirement for engine durability is that the *powertrain* must meet a 50 percent probability of achieving 4000 miles without a durability failure [Ref. 25, p. 10]. The power train consists of the engine, transmission and final drives.

AlliedSignal made the claim that a new engine will achieve a Mean Time Between Overhaul (MTBO) of approximately 2200 hours (with improved recuperator) and that an overhauled engine will demonstrate a MTBO between 300-600 hours. The armor school had difficulty in responding to this point of contention for the following reasons:

- Data specifically addressing time between engine failure and replacement is scarce. Data supplied from the field depicts time between engine replacement varying from 2200 hours to 732 hours [Ref. 24, p. 4]. Sources do not differentiate between the use of a newly-manufactured engine and those engines that have had modules previously replaced.
- The Army had no requirement to track overhauled engine durability statistics. Therefore, data regarding overhauled engines was severely lacking.

The lack of hard statistical evidence prompted the armor center to view with skepticism, AlliedSignal's recommendation to continue the purchase of either new AGT 1500's or remanufactured engines. The Army decided that it must gather data to prove the actual time between failures of overhauled engines.

3. Engine Testing

The Army conducted testing of overhauled engines for the following reasons: 1) there was low confidence in available overhauled engine data, 2) overhauled engine durability was unknown, 3) good overhauled engine durability data is essential to accurate analysis, 4) the test should provide ample data to conduct a thorough evaluation of engine durability.

a. Conduct Of The Test

Program Management Office (PM) Abrams initiated a 25 engine evaluation spanning the period from February 1993 to May 1994 at a cost of \$5M. All but one of the test engines had been overhauled to the latest Depot Maintenance Work Requirement

(DMWR). All four modules on all engines had been overhauled, and selection of the engines was conducted at random. Ten engines were sent to the National Training Center (NTC) for use by rotational training units. This utilization by troops would provide operational test conditions. Seven engines were sent to Yuma Proving Grounds (YPG) and eight engines were sent to Aberdeen Proving Grounds (APG). The engines sent to YPG and APG were evaluated to the tank-level durability requirement. Test and evaluation vehicles at these two locations were weighted to 67.7 tons in order to closely resemble current production vehicle combat-loaded weight [Ref. 25, p. 2].

Each engine was run until it failed. After engine failure verification, each engine was sent to AlliedSignal for a detailed failure analysis. This failure analysis identified the specific cause of the failure and highlighted any other issues with the overhaul process or configuration [Ref. 26, p. 2]. The detailed failure analysis was sent to ANAD. ANAD reviewed AlliedSignal's findings and responded accordingly. These two sources provided verification of processes, quality, overhaul activity, or DMWR associated failure causes.

b. Engine Requirement

The minimum engine durability requirement is 8,281 MMBF [Ref. 22, p. 3]. This figure is the minimum engine durability to fully satisfy the sustainment and M1 and M1A2 Tank Upgrade Program requirements.

The test utilized an engine durability failure definition of any malfunction that, after troubleshooting in accordance with published technical manuals, requires a module replacement.

c. Evaluation Results

There is only one definable, quantifiable engine-level requirement for durability. This standard is part of the tank-level powertrain durability requirement. Therefore, the evaluation of overhauled engine durability centers on the results of the

fifteen engines tested at APG and YPG. Results as of May 25, 1994, indicated an overhauled engine durability of 3,860 MMBF. This is well below the tank-level requirement of 8,281 MMBF [Ref. 26, p. 3].

The detailed analysis to both fully evaluate failure causes and determine recommended improvements to the overhaul process included all 23 engine failures and detailed failure analysis. At the time of final analysis, AlliedSignal and ANAD had responded to 18 detailed failure analysis reports.

d. Recommended Overhaul Process Improvements

A list of overhaul process improvements was generated from the detailed failure analysis, depot evaluation, PM Abrams and TACOM review, and durability projections. The recommended improvements will improve overhauled engine durability from 3,860 MMBF to a projected 9,124 MMBF [Ref. 26, p. 4]. This is a 136 percent improvement and exceeds the engine durability requirement. Of course, as with most improvements, comes a higher price tag.

The recommended service life extension program (SLEP) will increase the unit funding cost (UFC) from \$64, 876 to a projected price of \$91, 606, or a 41% increase [Ref. 26, p. 4]. This cost is significantly lower than the price tag of a new engine at \$500,000 and that of a remanufactured engine at \$260,000.

The following is the list of recommended changes to the overhaul process:

- Incorporate Improved Recuperator ECP.
- Do not mix resistance and laser style recuperator plate pairs.
- Implement Turbine Blade parts reclamation procedure.
- Use 100 percent laser welding recuperator plate pairs during overhaul of an engine.
- Require mandatory replacement of the combustor curl.
- Revise DMWR minimum output power requirement from 1350 to 1400 shaft horsepower.

- Implement detailed overhauled engine data collection at the depot.
- Institute periodic control testing of overhauled engines.
- Implement a quality and process audit and review program.
- Rewrite the AGT 1500 DMWR.
- Develop and implement process sheets.

e. Conclusions

The Army utilized the 25 engine test and detailed analysis to arrive at the determination that the improved overhauled engine program is the most cost-effective solution to meet it's tank engine requirements. This program will satisfy the sustainment requirements for the fielded tank fleet, the M1 and M1A2 Upgrade Program and the armor community's war fighting needs.

C. ANALYSIS

This section will analyze the two options in respect to their ability to support the three alternatives to newly-manufactured engines

1. Option One: The Army Mothballs SAEP, Retains AlliedSignal as Contractor and Relocates to Another Facility

- Overhauled Engines: this option provides the Army the capability to perform overhaul work on the engines. Overhaul of the engine includes the service life extension program (SLEP), which is designed to provide engineering improvements to increase engine durability. It does provide the capacity for AlliedSignal to continue both the manufacture of critical sole source parts, and technology insertions. The main drawback to this course of action is that there is increased risk associated with the movement of certifiable processes. While AlliedSignal is remaining as the contractor, the shutting down of a process,

movement of equipment, and training of a workforce could lead to initial quality deficiencies.

- **Remanufactured Engines:** relocating the operations to a smaller facility, without moving the necessary equipment, will not support remanufacturing of AGT 1500 engines. Floor space for remanufacturing of engines is approximately the same as for production of newly-manufactured engines. Should the SLEP not increase durability to acceptable levels, the capacity to produce remanufactured engines may not be available under this option. Testing of actual remanufactured engines would have to take place to ascertain if engine durability would achieve the tank level requirement.

2. Option Two: The Army Downsizes SAEP, and Institutes a Dual-use Lease With AlliedSignal

The analysis of this option is based on SAEP's retention throughout the time period that support of the AGT 1500 is required. Relocation after the three year evaluation period would generate the advantages and disadvantages mentioned in Option One's analysis.

- **Overhauled Engines:** would benefit from a stable environment and workforce. Retention of SAEP would not require training and certification of the workforce and manufacturing processes. This reduces the Army's risk of supporting its tank fleet and depot engine overhaul program with spare parts and related logistical support.
- **Remanufactured Engines:** the stable workforce and ample floor space at SAEP, provide the Army with an alternative to newly-manufactured and overhauled engines. The machinery that is expected to remain at SAEP will provide the capacity for production of both newly-manufactured and remanufactured engines, and component parts for the SLEP. Remanufactured engines could be a viable alternative to SLEP engines, if performance of these

engines is found to be lacking. Remanufactured engines may also be a more cost-effective alternative than newly-manufactured engines.

D. SUMMARY

The Army analyzed the three alternatives to newly-manufactured engines: overhauled, SLEP overhauled, and remanufactured engines. After extensive modeling, simulation, and actual testing, the Army arrived at the determination that SLEP overhauled engines would provide the necessary performance and durability required to support the tank fleet. TACOM believes that either option will be able to provide the support necessary to maintain both the tank fleet and meet user requirements.

The relocation of AlliedSignal's capabilities will increase the risk of both performing engine overhaul and production of quality components. Eventually, the familiarity with manufacturing processes will enable the workforce to produce quality components and service. The retention of SAEP will provide the experienced workforce, equipment, and floor space that allows the Army to mitigate this risk. The SAEP affords the Army the ability to conduct engine overhaul work, while maintaining both remanufacturing and new engine production capacity. Therefore, from an operational effectiveness standpoint, the retention of SAEP provides the Army both the best and least risky opportunity to acquire quality overhauled engines and spare parts to support the tank fleet.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. GENERAL CONCLUSIONS

The tank engine industrial base is an essential element of the armor force's readiness posture. Although there are commercial capabilities available to produce an acceptable engine, both the cost and time of developing a new source and engine design are prohibitive. Allowing the tank engine industrial base to go "cold" could jeopardize the tank fleet's readiness, as well as future development of turbine engines for ground vehicle applications.

The Army, Congress, and AlliedSignal committed themselves to preserving the tank engine industrial base. The Army requested from Congress more than \$180M over the next three years to maintain its capability to produce tank engines [Ref. 20, p. 9]. AlliedSignal and the Army have begun the downsizing of SAEP to create a more cost-efficient facility. Additionally, the Army and AlliedSignal are negotiating a dual-use lease of SAEP to allow an expanded commercial usage of idle IPE. The potential increase in private industry utilization of a GOCO facility can reduce the cost of Government items by lowering the overhead rate. The Army made a determination to maintain the SAEP for a period of at least three years.

During this time period the Army will evaluate SAEP's ability to produce affordable spare parts and logistical services. At the end of this evaluation period, the Army will decide if it is more cost-effective to remain at SAEP, or to relocate operations to another, more cost-efficient facility.

B. SPECIFIC CONCLUSIONS

The following conclusions encapsulate the advantages and disadvantages of the two options for preserving the tank engine industrial base. A comparative analysis of the two options will succeed the summary.

**1. Option One: The Army Should Mothball SAEP, Retain
AlliedSignal's Capabilities and Relocate the Facility**

This course of action allows the Army to retain the production of spare parts, and both engineering and logistical support necessary to maintain the tank fleet's readiness. The Army would totally lay away SAEP, conduct extensive layoffs of the workforce, and either sell or mothball unnecessary equipment.

a. *Advantages of Implementing This Option*

- The production of spare parts and SLEP overhauled engines can be executed under this option.
- Costs of spare parts and both engineering and logistical support will be lower in the long run.

b. *Disadvantages of Implementing This Option*

- Requires upfront funding of \$26.4M for a spares build-ahead program.
- Unless equipment and 8,000, the Army does not need anymore new engines.
- The workload generated from spare parts production and overhaul of engines will allow for the preservation of the tank engine industrial base, including engineering support.
- Unless equipment and floor space are provided to allow newly-manufactured engine capacity, the Army will not have the ability to rapidly produce new engines for either its own use or FMS.
- Utilization of an untrained workforce will increase risk of meeting production schedules and quality standards.
- The uncertainty of the development, production, and fielding of the follow-on main battle tank could leave the Army with the M1A2 for the next 20 to 30 years.

2. Option Two: The Army Should Downsize SAEP, Retain AlliedSignal's Services, and Establish a Dual-use Lease

This option allows the Army to sustain SAEP for the near term and retain, intact, AlliedSignal's capability to: manufacture spare parts, provide both logistical and engineering support, as well as perform engine overhaul work. Additionally, this option maintains the capacity to manufacture new engines.

a. Advantages of Implementing This Option

- The experienced "core" workforce is retained intact.
- The stability of both the workforce and manufacturing processes provides continued quality assurance of spare parts and support activities.
- Retention of IPE and floor space will mitigate the risk of meeting unforeseen demands for new engines.
- Retention of engineering knowledge will assist in future research and development of gas turbine engines.
- The retention of the capacity to produce newly-manufactured engines decreases the amount of time required to mobilize the production line to surge capacity in a time of emergency.

b. Disadvantages of Implementing This Option

- The costs of spare parts and logistical support are increased due to extremely high overhead rates.
- Attempts to lower overhead rates could lead to a termination of engineering support.

3. Comparative Analysis

Analysis of the courses of action was conducted by comparing the following criteria. Workforce issues, discussed in Chapter III, include factors such as: 1) retention of a "core" workforce, 2) training and certification times for the workforce and manufacturing processes. Costs discussed in Chapter IV, incorporate issues of: 1) facility layaway, 2) closure penalties 3) spare parts build-ahead program 3) environmental restoration programs, 4) human resources, 5) equipment removal, 6) logistical support, 7) SLEP, and 8) spare parts. Chapter VI examined operational effectiveness issues to include: 1) remanufactured and overhauled engines, 2) engine durability and performance requirements, and 3) SLEP.

Option One, the layaway of SAEP and relocation of overhaul capabilities, spare parts production, and both logistical and engineering support is the most cost-effective alternative. Implementation of either option incurs the estimated \$42M cost of reestablishing the production line. Option Two is the least cost-effective alternative; as the predicted overhead rates increase the cost of spare parts and logistical support to excessive levels. Option Two could become competitive in a cost perspective if the restructuring of SAEP reduces the overhead rate to an acceptable level. Additionally, if the Army is forced to implement the entire \$422M environmental remediation requirement once SAEP is vacated, then the cost to implement either option would almost be equal.

Option One is the best option from the operational effectiveness, mobilization, and workforce perspectives. The retention of a skilled, experienced workforce and uninterrupted manufacturing process, results in the continued quality of the product. The retention of SAEP provides a constant production of spare parts and logistical support for the engine overhaul program. Relocation of the facility results in an increased risk of reestablishing manufacturing processes and training of a new workforce. During this training and certification period, quality of workmanship can be expected to impact operational effectiveness. The retaining of SAEP also mitigates the amount of risk associated with mobilization of the industrial base.

The SAEP will retain the capacity to provide surge production of at least ten newly manufactured engines per month. Current plans for location of the facility do not include surge capacity. The ability to produce new engines will greatly reduce the Army's risk of failing to meet unexpected demands for newly-manufactured engines generated from emergencies, FMS, or both.

Either option provides the Army the ability to support its current tank fleet and the M1A2 Upgrade Program with quality engines, spare parts, and support activities. The difference is centered on timing. Option Two's ability to produce quality service is likely to take more time to establish. Option One will not require the additional time to reestablish the learning curve and recertify manufacturing processes. If relocation is deemed necessary, the Army plans to utilize a spare parts build-ahead program. This program will mitigate the risk of meeting spare parts requests by maintaining a stockage of spare components. In conclusion, the Army believes that SLEP AGT 1500 engine will meet the needs of the tank fleet, and preserve the tank engine industrial base, at least for the near term. Within the scope of this thesis, the recommended solution for preserving the tank engine industrial base is to continue operation of SAEP until SLEP engines prove that they can meet performance and durability requirements, and it is no longer cost-effective to remain at SAEP.

4. Additional Conclusions

The following additional conclusions were brought forth during the research of this thesis. These observations could favorably impact upon the Army's ability to preserve the tank engine industrial base into the future.

a. Dual-use Leases

Dual-use leases will assist the Government and private industry reduce the cost of acquisitions of military equipment. With the reduced number of large scale production runs of military items, the DoD is forced to mothball large industrial

complexes, such as SAEP. The establishment of dual-use leases will enable private industry to utilize existing facilities (for a cost) to produce commercial items. This action will eliminate the DoD's requirement to provide maintenance and caretaking of these mothballed facilities. The DoD must establish policies and guidance that will allow for rapid institution of dual-use leases at GOCO facilities.

b. Subcontractor Base

The DoD should monitor the welfare of the third-tier vendor base. These small businesses play an integral role in the DoD industrial base. DoD must that realize the loss of small businesses can hamper DoD's ability to procure vital components to maintain system's readiness and upgrades of existing fielded equipment.

c. Dual-use Technology

Once requirements for newly-manufactured items cease, the selection of technologies that provide a military and commercial application reduce DoD's risk of providing support of fielded systems. Additionally, DoD must thoroughly evaluate acquiring systems and components that can be utilized in a variety of military applications. An engine that can be employed in a tank, a self-propelled artillery system, a armored recovery vehicle, or an infantry fighting vehicle will be of great benefit to the Army. The commonality of components, such as engines, provides the following advantages: 1) reduced cost of spare parts and logistical support 2) fewer repair specialties and related training, 3) reduction of inventory requirements for spare parts, and 4) enhanced synchronization of maneuver forces on the battle field.

C. RECOMMENDATIONS

The following recommendations are made that will ensure the long-term preservation of the tank engine industrial base.

1. General Recommendations

The Army should retain SAEP and institute the SLEP to support the upgrade of existing AGT 1500 gas turbine engines. This course of action will preserve the industrial base and allow for the incorporation of future technological insertions to the design of the engine to meet any changes in performance requirements. Execution of this option reduces the risk of meeting unforeseen demands and mobilization requirements.

2. Specific Recommendations

The following are additional recommendations made within the scope of this thesis:

- Increase Government support for dual-use leases.
- Monitor the third-tier vendor base's health during the restructuring process.
- Thoroughly evaluate the use of dual use-technology and applications in DoD systems.
- Develop policies and guidance that reduce the amount of time to negotiate and implement dual-use leases at GOCO facilities.
- The Army must conduct actual testing of SLEP AGT 1500 engines to ascertain their performance and durability.

3. Recommendations for Further Research

The following areas should be studied further and in greater detail to ascertain their impact on the preservation of the tank engine industrial base during the implementation of the current proposed option. Some of these issues will have additional applications to other DoD agencies grappling with similar issues.

- Dual-use leases: What is the current DoD policy governing the establishment of dual-use leases and is there a need to change this policy to enhance the implementation of dual-use leases?

- Reconstitution: Can the tank engine industrial base reestablish itself after a prolonged shutdown?
- Workload allocation between original equipment manufactures and depots: Should the depot system continue to provide overhaul and upgrade capacity for fielded systems or should this workload be returned to industry to keep the industrial base “warm”?
- Dual-use technologies: Can dual-use technology provide industry the capability to readily transfer from commercial production to military production?
- Government-owned and contractor-operated facilities: Has the reduced need of large production runs of major end items eliminated the need for GOCO facilities, and can COCO facilities provide the assets to meet future DoD needs?

APPENDIX A. DEFINITIONS

The following definitions were derived from briefing slides obtained from TACOM.

1. Durability: The probability that an item will successfully survive usage to meet its requirement

2. Engine Failure: After troubleshooting in accordance with current technical manuals requires an engine or modules replacement. A failure always leads to a replacement, but a replacement is not always caused from a failure.

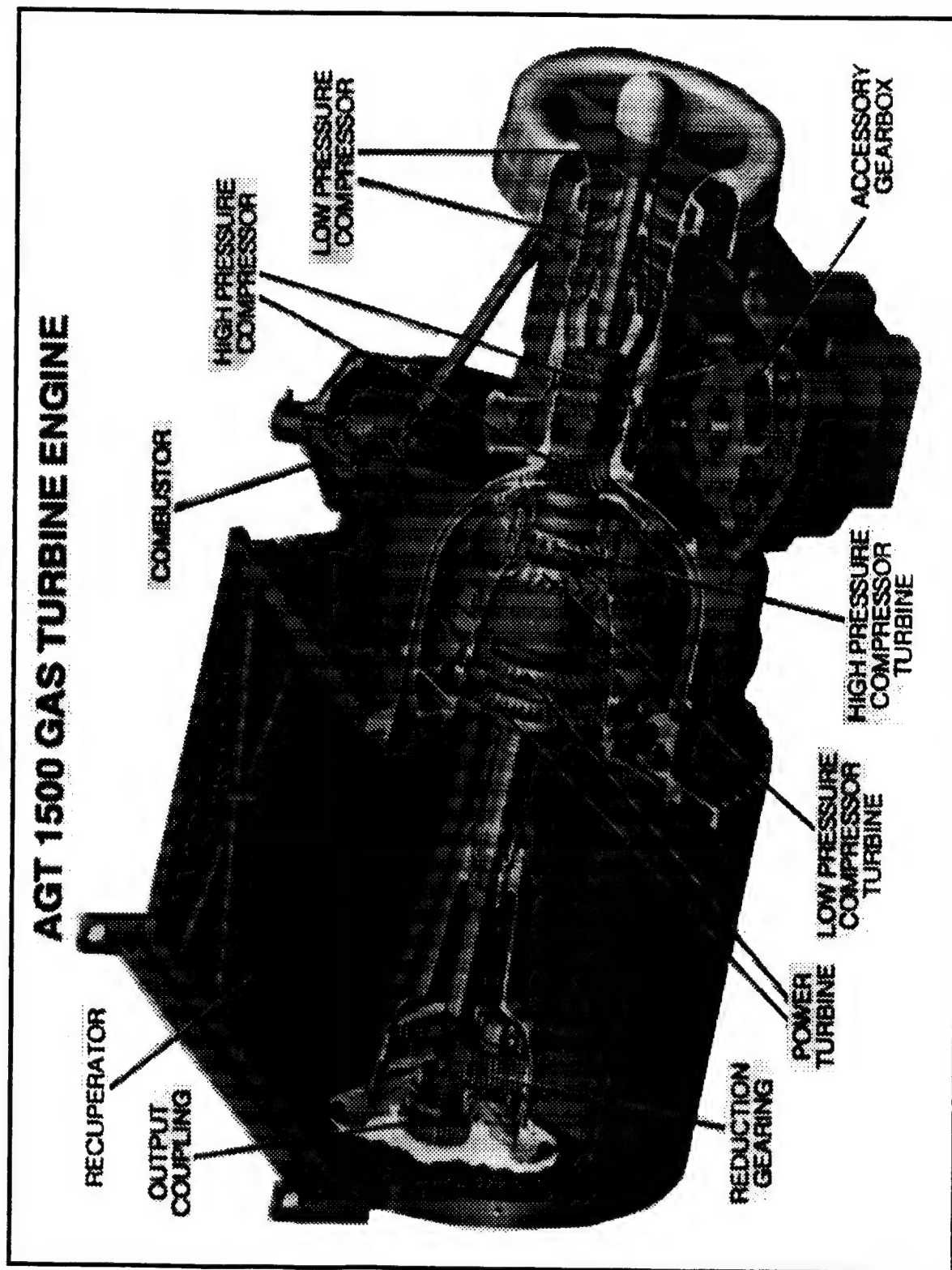
3. MTBR and MMBR: Mean Time Between Replacement and Mean Miles Between Replacement: Replacement is an engine or module replaced for cause.

4. MTBF and MMBF: Mean Time Between Failure and Mean Miles Between Failures. A failure which is engine caused and requires either an engine or module replacement for cause.

5. Industrial Plant Equipment (IPE): IPE is equipment used in the manufacturing, maintenance, supply, processing, assembly or research and development operations of an item. It includes machinery and equipment capable of: cutting, grinding, shaping, forming, measuring, heating or altering the physical and electrical, or chemical properties of material, components, or end items [Ref. 14, p.149].

6. RO: Requirements Objective: Is the minimum objective quantity of an asset desired to be stocked at any given time.

7. AFAO: Army and Foreign Acquisition Requirement Objective.



REFERENCES

1. Blackwell, James, "Deterrence in Decay, The Future of the U.S. Defense Industrial Base," *The final report of the CSIS Defense Industrial Base Project*, Washington, D.C. Center for Strategic and International Studies, May 1989.
2. U.S. Army Tank Automotive Command, Production Management Division, "Tracked Vehicle Industrial Base Report for Mr. Frank Kendall, OSD, Director of Tactical Systems," November 17, 1993.
3. Kafkalas, Lieutenant Colonel, U.S. Army, DPRO AlliedSignal, Memorandum, "Tank Engine Industrial Base AGT 1500 (Automotive Gas Turbine 1500 HP)," September 14, 1993.
4. Raffiani, Joseph, Jr., Major General, U.S. Army, Memorandum, "Follow-up, DoD IG Report 93-008, Termination of Procurement of Tank Engines and Modules for the M-1 Tank (Project No. 1LE-0067.01)," February 26, 1993.
5. U.S. Army Tank Automotive Command, Production Management Division, "History of the AGT 1500."
6. Inspector General, Department of Defense, "Quick-Reaction Report On Termination of Tank Engines and Modules For The M-1 Tank (Project No. 1LE-0067.01)," October 19, 1992.
7. The Defense Science Board Task Force, "Report On Tracked Vehicle Industrial Base," April 1994.
8. Dausman, George E., Acting Assistant Secretary of the Army (Research, Development and Acquisition), Memorandum, "Tank Engine Industrial Base," April 20, 1994.
9. U.S. Congress, "Abrams Tank FY95 Congressional Track Authorization Conference."
10. Assard, David G., "Statement of David G. Assard President of Textron Lycoming Turbine Engine Division Before The Defense Conversion Commission, Groton, Connecticut," September 17, 1992.
11. Textron Lycoming, "TACOM/Textron Lycoming Executive Discussions," December 16, 1993.
12. Kitfield, James, "Shrinking the Industrial Complex," *Government Executive*, August 1993.

13. Monroe, James, W, Major General, U.S. Army, Memoradum, "Abrams Tank AGT 1500 Engine Industrial Base," April 15, 1994.
14. U.S. Army Tank-Automotive Command, Briefing Slides, "AGT 1500 Tank Engine Industrial Base," April 18, 1994.
15. Kolb, George, Senior Engineer, AlliedSignal Inc. Memorandum to the Author, December 15, 1994.
16. Hernandez, Juan J. "A Comparative Analysis Of Options For Preserving The Tank Industrial Base," March 1993.
17. Young, Prince, Jr. U.S. Army Tank-Automotive Command, Briefing Slides "AGT 1500 Engine Industrial Base," May 19, 1994.
18. U.S. Army Tank-Automotive Command, Unpublished Briefing Slide "SAEP Re-Start Schedule (Cold Base)."
19. U. S Tank-Automotive Command, Point Paper, "Abrams AGT 1500 Tank Engine Industrial Base," January 18, 1995.
20. Glashow, Jason, "U.S. Army Guards Tank Engine Base," *Defense News*, January 9, 1995.
21. Powell, Colin L., General, U.S. Army, Chairman of the Joint Chiefs of Staff, "National Military Strategy of the United States," January 1992.
22. Schapira, Charles, Chief Engineer, AlliedSignal, Letter To The Author, "Captain Sanford's Thesis on the Industrial Base," December 5, 1994.
23. U.S. Army Tank-Automotive Command, Briefing Slides, "AGT 1500 Engine Industrial Base Plan," December 21, 1994.
24. Combat Development Center, Fort Knox, Ky. "AGT 1500 White Paper," July 1, 1993.
25. Weir, William., Lieutenant Colonel, U.S. Army, Program Manager Abrams Tank System, Briefing Slides, "Abrams Tank AGT 1500 Engine Evaluation," April 21, 1994.
26. Weir, William., Lieutenant Colonel, U.S. Army, Program Manager Abrams Tank System, "Final Report On 25 Overhauled AGT 1500 Abrams Tank Engine Durability Evaluation," May 25, 1994.

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